# MENTAL MODELING
# HAZARD COMMUNICATION PROGRAMS
# WITHIN A SELECT GROUP
# IN INDUSTRY.

By

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# CHAPTER I

## THE PROBLEM AND ITS SETTING

### Introduction

*Mental modeling* (MM) uses influence diagrams to carefully examine knowledge structures. Lay persons' influence diagrams are compared to expert diagrams identifying areas of ignorance, confusion or misconception. Mental modeling is receiving considerable attention in applied research (Genter and Stevens, 1983), in education, engineering, and professional journals.

Interacting in various environments, with other people and technology, people form internal mental models of themselves and of the things with which they are interacting. MM is characterized by careful examination of the way people understand a certain domain of knowledge.

A mental model is a mapping from a domain into a mental representation that contains the main characteristics of the domain. These models have been proposed in particular as the kind of knowledge structures that people use to understand a specific domain (Jungermann, Schütz, and Thüring, 1988). In other words, two influence diagrams are created representing the knowledge of the lay peoples' understanding and that of the experts for some particular domain (Figure 1). The models are compared and the differences between the two can be used to point out areas of ignorance, confusion, or misunderstanding (Johnson-Laird, 1983). An example of MM and its fundamental principles will be provided in Chapter III.

Many researchers believe that MM is vital to learning and believe it holds the key to solving many of the problems encountered with teaching. It can be used to develop education and enhance communication efforts designed to reduce "ignorance", "confusion", or "misconceptions". Ultimately, the better the model, the better the teaching and educational processes can be improved.

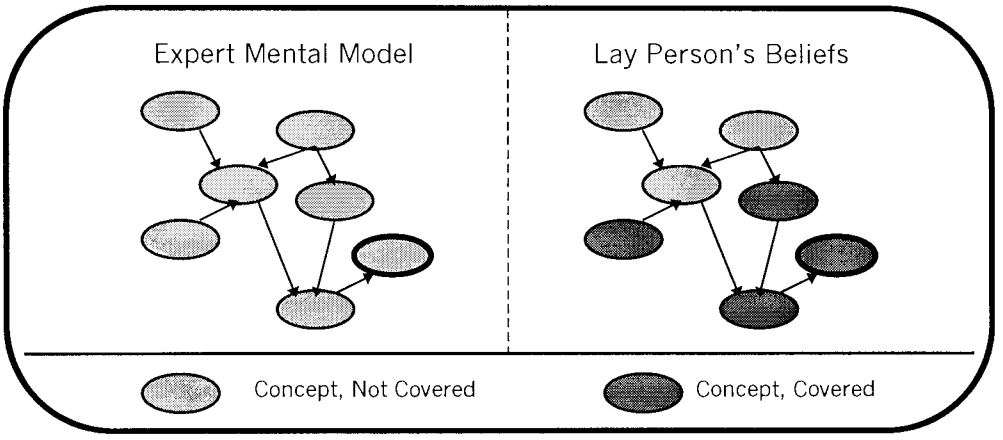



**Figure 1**. Mental Modeling Example

The *Hazard Communication Standard* will be used as the vehicle to test MM as a diagnostic tool to determine *local specialist's* knowledge. After an exhaustive literature search, a published study of this nature was not found that would help companies evaluate the effectiveness of their current hazard communication program practices. Many references are available to guide safety managers/professionals to enforce the regulations imposed by the *Occupational Safety and Health Administration* (OSHA), however, no published method exists for examining hazard communication programs and to gauge their effectiveness in the workplace.

## The Importance of the Study

The perception of hazard communication today can be compared to our perception thirty years ago. At that time, there was significant potential for chemical exposure within the nation's workforce. Data indicates that approximately 32 million workers were exposed to one or more chemical hazards of an estimated 575,000 existing chemical products used each year (Handbook on Hazardous Materials Management, 1995).

The potential for occupational exposure was of great concern because chemical exposures caused a variety of health effects which could impair an individual's health and in some extreme cases lead to disabling diseases or even death. Some chemicals may be safety hazards and have the potential to cause fires, explosions and other serious accidents which in turn may lead to serious injuries or even death (Goetsch, 1993).

Today, OSHA has set safety and health standards for almost all non-governmental employers to help protect their workers. One of its most significant contributions is the

Hazard Communication Standard, 29 CFR 1910.1200, created to reduce the incidence of chemical source illness or injury (OSHA #3021, 1987). Through education and training, workers gain enough knowledge about protective measures or actions to decrease the likelihood of occupationally related chemical source illnesses or accidents.

By using MM and survey methods, information may be gained to explore training effectiveness. If MM can be used to gauge command of the Hazard Communication Standard, then the better educated their employees will become and the less likely an accident or fatality will occur. If successful, later applications of MM may include community right-to-know programs, personal protective equipment training, confined space entry permitting and training, and OSHA's 40 Hour HAZWOPER training.

## The Statement of the Problem

Currently published methods for evaluating program management's command of hazard communication are weak at best. Most companies do not know if their employees have retained and can apply the tools of hazard communication in the workplace. The purpose of this study is to attempt to: (1) determine if MM can be used as a diagnostic tool to measure *local specialist's* knowledge using OSHA's 29 CFR 1910.1200 Hazard Communication Standard as the test vehicle and (2) to obtain quantitative information concerning current employer practices at several Oklahoma companies.

An attempt will be made to answer the following specific questions:

1. Can MM be used as a diagnostic tool to assess the quality of local specialist's knowledge? If so, what are the procedures or steps to develop such a regulatory expert mental model that identifies knowledge structures conveying the appropriate regulatory information?
2. Does MM offer insight into potential areas of ignorance, confusion or misconceptions concerning the Hazard Communication Standard? Are these misunderstandings being transmitted to employees through *employee right-to-know* (ERTK) training?
3. What practices are used to educate and inform employees of their rights and responsibilities under OSHA's Hazard Communication Standard?
4. Given that employees are trained in hazard communication, what have they retained through their training?
5. If MM can be used as a diagnostic tool, identify additional applications of regulatory MM that can be used to assess specialist's knowledge?

## Constraints

The following constraints are imposed for the purpose of this study:

1. Only three Oklahoma companies that have an established ERTK program will be selected.
2. The expert influence diagram is based on OSHA's 29 CFR 1910.1200 Hazard Communication Standard.
3. The expert diagram will be validated by two experts, Dr. Wayne Turner, and Jim Hansen.
4. Three professional local hazard communication directors (*"specialists"*) will be thoroughly examined to compare their knowledge of the Hazard Communication Standard and that of the expert, 29 CFR 1910.1200.
5. A simple random sample of employees at each company will be provided a questionnaire, each limited to one questionnaire per respondent, to measure their understanding of hazard communication.

## Deliverables

The following will be delivered with this study:

1. A regulatory expert mental model, or influence diagram, of the OSHA Hazard Communication Standard requirements (29 CFR 1910.1200)
2. Three knowledge maps of local company hazard communication directors will be developed to gauge their understanding of the Hazard Communication Standard based on the expert MM.
3. An examination of the use of MM to judge "local" understanding of regulatory requirements or educational programs.
4. Results of ERTK questionnaire, administered to three different Oklahoma manufacturer's employees, gauging the employees' understanding of the company's hazard communication program.
5. Revised procedure for using MM to measure local specialist's knowledge of areas.
6. A list of additional areas where MM may be used with justification.

## Methodology

### Mental Modeling

The expert influence diagram, based on the regulatory information found in 29 CFR 1910.1200, was constructed in a hierachial structure. Each node represents a basic concept or event directed towards the central theme – hazard communication. Only those nodes or concepts pertaining to informing or training employees in HazCom will be considered in this analysis.

Local specialists at each company were interviewed in an open-ended format on their knowledge of Hazard Communication. All interviews were taped and transcribed, and their knowledge of HazCom was used to show discrepancies between the regulatory expert mental model and their knowledge of the ERTK standard.

### Questionnaire

A questionnaire generated to probe the knowledge of employees in the workplace was designed to determine the level of knowledge and gauge training effectiveness. The ERTK questionnaire was provided to each company in the study. Survey questions ranged from specific hazard communication terminology and concepts, personal protective equipment, and in-house safety evaluation. A 10 question multiple choice test on ERTK was also provided.

The completed questionnaire was transcribed onto a spread sheet and entered into a data set per company. Statistics were performed on each company's grouped responses to reveal the percentages of each response for each question on the questionnaire.

## The Definitions of Terms

In order to clarify the wide variety of definitions used in MM and hazard communication, the following terms are defined in this study:

*Acute health effect* - usually occurs rapidly following a brief exposure, usually at high levels.

*Belief System* - a person's mental model reflects his/her belief about the physical system acquired through observation, instruction or inference.

*Chronic health effect* - a long, continuous health effect brought about by repeated long-term exposure, usually at low levels.

*Employee right-to-know* (ERTK)- see *Hazard Communication Standard.*

*Hazard Communication Standard* - also known as *Hazcom* or *employee right-to-know* (ERTK), as defined in OSHA's 29 CFR 1910.1200; simply states that every person who works with hazardous substances has the *right-to-know* about the hazards of those materials.

*Health hazard* - a chemical can cause acute or chronic health effect on an exposed individual; exposure may result in cancer, damage to the lungs, skin, eyes, blood or liver, irritation of skin, corrosion, and sensitivity.

*Hazardous material* - is a material that, when used, poses measurable long- or short-term health (body) and/or physical or environmental hazards.

*Hazardous waste* - a waste material is considered hazardous if it is listed in the Resource Conservation and Recovery Act (RCRA) or possesses one of four characteristics of hazardous waste as defined by RCRA.

*Influence diagrams* - often hierarchical in structure, these diagrams are a directed network representing the dependencies and events in a process used to perform structural probabilistic assignments.

*Local specialists* - a select and finite population of professionals with a stated number of years of experience within the control occupation.

*Mental modeling* (MM) - a careful examination of the way people understand some domain of knowledge via the revelation of influence diagrams that can be viewed as associational models of a process, event-sequence or phenomenon (Bostrom *et al.*, 1992).

*Occupational Safety and Health Administration* (OSHA) - in 1970 within the Department of Labor, was created to set safety and health standards for almost all non-governmental employers.

*Physical hazard* - those chemicals which exhibit some physical property under certain environmental conditions (i.e. flammability, reactivity, explosivity, combustibility, stability).

*Predictive Power* - a mental model should have the ability to understand and anticipate the behavior of a physical system.

*Target system* - the system the person is learning about or using.

# CHAPTER II

## REVIEW OF OSHA's HAZARD COMMUNICATION PROGRAM

### Overview of OSHA and Hazard Communication

Until the 1970's, no comprehensive provision existed for the protection of employees from health hazards and workplace safety. Many of the chemicals used had no prior study of hazardous effects on workers and adherence to safe practices and exposures (OSHA #3071, 1985). The Occupational Safety and Health Act was passed by the United States Congress in 1970 and became effective 1971. Under this act the Department of Occupational Safety and Health Administration (OSHA) was created within the Department of Labor to set safety and health standards for almost all non-governmental employers (OSHA, April 1996).

Since its inception, OSHA has promulgated a variety of health and safety standards. One standard in particular is intended to ensure that all workers are able to identify the hazards they work with through a comprehensive hazard communication program (OSHA #3076, 1986). This standard is commonly called "*Hazcom*" or the "*Employee Right-to-Know* Law" (ERTK), and can be found in the Code of Federal Regulations, at Title 29 Code of Federal Regulations Part 1910.1200 entitled Hazard Communication Standard (Appendix A). The standard is quite long but it simply states that every employee who works with hazardous substances has the right-to-know about the hazards of those materials (OSHA #311, 1995).

An employer, for purposes of compliance with 29 CFR 1910.1200, is a person engaged in a business where chemicals are used, distributed, or produced for use or distribution. It states that regardless of the number of employees in the workforce, the Hazard Communication Standard is still applicable (see Table 1). One difference between this rule and many others adopted by OSHA is that it is performance-oriented. That means that employers have the flexibility to adapt the rule to the needs of their workplaces, rather than having to follow specific, rigid requirements. However, it requires employers to exercise more judgment to implement an appropriate and effective program.

The requirements of the rule that deal specifically with the hazard communication program are found in the standard in paragraphs (e), written hazard communication programs; (f), labels and other forms of warning; (g), material safety data sheets; and (h), employee information and training.

| Compliance Checklist |
|---|
| 1. Obtained a copy of the rule |
| 2. Read and understood the requirements |
| 3. Assigned responsibility for tasks |
| 4. Prepared an inventory of chemicals |
| 5. Ensured containers are labeled |
| 6. Obtained MSDS for each chemical |
| 7. Prepared written program |
| 8. Made MSDSs available to workers |
| 9. Conducted training for workers |
| 10. Established procedures to maintain current program |
| 11. Established procedures to evaluate effectiveness |

Table 1. Checklist for Compliance (OSHA, #3111 1995)

All programs must include provisions for container labeling, collection and availability of material data safety sheets (MSDS), and an employee training program (OSHA #3111, 1995). The program is to be written and should include how the employer plans to meet the criteria of the standard regarding labels and labeling, MSDSs, training, compliance, informing employees of the hazards associated with non-routine tasks, as well as chemicals which pose either a *physical* or *health hazard* in work areas. Employers should also identify methods to inform contractors in manufacturing facilities of the hazards to which their employees may be exposed.

The goal of a hazard communication program is to reduce the incidence of chemical source illnesses or injuries. Workers will learn of any job-related health risks for themselves. Through education and experience, they are then able to make informed decisions about the need for corrective actions. The law also helps employers protect their workers (Figure 2). As workers acquire more understanding of the health effects and chemical hazards of toxic substances, they are more likely to comply with safe work practices.

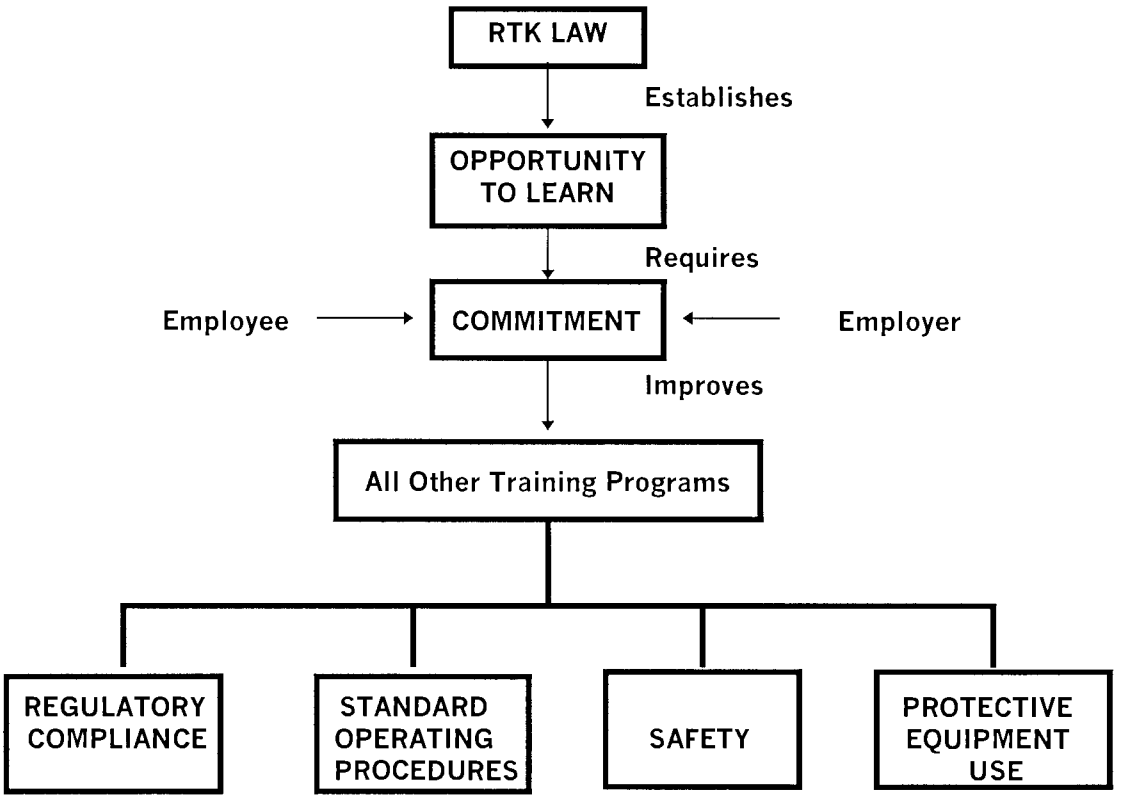



Figure 2. Impact of Employee Right-To-Know

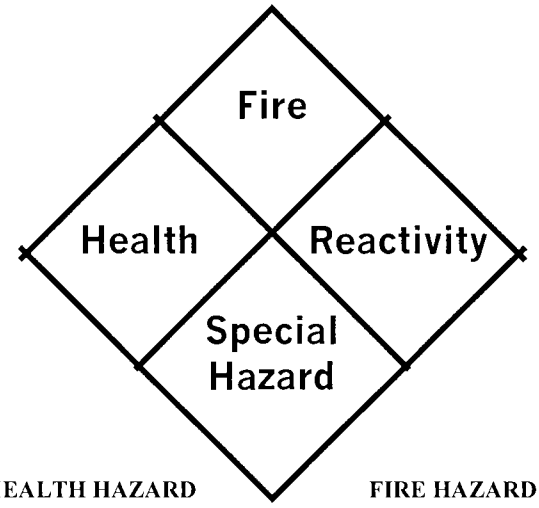
Training is critical to effective hazard communication and should be used at the time of initial assignment, and whenever a new hazard is introduced into the work area. Training serves to explain and reinforce the information presented to employees through the written medium of labels and MSDSs. These two mediums are only successful when employees understand the information presented and are aware of the action to be taken to avoid or minimize exposure, and thus the occurrence of adverse effects (OSHA #3088, 1995)

## The Labeling and Marking System

Chemical manufacturers, importers, and distributors are required to ensure containers of hazardous chemicals leaving the workplace are labeled, in English, with the identity of the hazardous chemical, appropriate hazard warnings, and the name and address of the chemical company (section 1910.1200(f)(1), (4), (5), (6), (7), (8), (9), and

(10)). This provides an immediate visual warning about the hazards of the chemical within the container. Companies are also responsible to ensure that labels do not conflict with those applied in accordance with the Department of Transportation regulations under the Hazardous Materials Transportation Act (Institute of Hazardous Materials Management, 1995).

Any label is sufficient as long as it conveys the required information. The best programs utilize a simple marking system that is readily recognizable and easily understood (e.g., National Fire Protection Association, Figure 3). Any worker should be able to quickly identify the general type and severity of that hazard.




**HEALTH HAZARD**
**4** - Deadly
**3** - Extreme Danger
**2** - Dangerous
**1** - Slight Hazard
**0** - No Hazard

**FIRE HAZARD**
**4** - Below 73°F
**3** - Below 100°F
**2** - Below 200°F
**1** - Above 200°F
**0** - Will not burn

**SPECIAL HAZARD**
**W** - Water Reactive
**OX** - Oxidizer
- Radioactive

**REACTIVITY**
**4** - May detonate
**3** - Explosive
**2** - Unstable
**1** - Normally Stable
**0** - Stable

Figure 3. The NFPA 704 Marking System

The primary information to be obtained from an OSHA-required label is an identity for the material and appropriate hazard warnings. The identity is any term which appears on the label, the MSDS, and the list of chemicals. All three sources of information should be linked together with one common name. The identity used by the supplier may be a common or trade name (e.g., "Slick 50"), or the chemical name (e.g., 1,2-dichloroethane). The hazard warning is a brief statement of the hazardous effects of the chemical (e.g., "flammable," "causes lung damage"). Labels frequently contain other information, such

as precautionary measures (e.g, "do not use near an open flame"), but this information is provided voluntarily and is not required by the rule. Labels must be legible, and prominently displayed. There are no specific requirements for size, color, or specified text.

The user is not required to label portable transfer vessels into which hazardous chemicals are transferred from labeled containers and intended for the immediate use of the employee who performs the transfer. According to the definition of immediate use, the container must be under the control of the employee performing the transfer and used within the work shift when the transfer has been made. Further labeling is not required if containers are labeled by the manufacturer or supplier.

## Material Safety Data Sheets

OSHA believes that all employees should be provided with thorough information on each hazardous chemical in their work area, including specific chemical names. Labels provide only a limited amount of information and are physically attached to a container. The role of material safety data sheets (MSDSs) under the rule is to provide detailed information on each hazardous chemical, including its potential hazardous effects, its physical and chemical characteristics, and recommendations for appropriate protective measures.

The standard requires chemical manufactures and importers to develop MSDSs, in English, for each hazardous chemical they produce or import (section 1910.1200(g)). There is no specified format for the MSDS under the rule, although there are specific information requirements. OSHA has developed a non-mandatory format, OSHA Form 174, which may be used by chemical manufacturers and importers to comply with the rule. An awareness of the use of MSDSs, and how to locate them is one of the most important points of the Hazcom program.

If the company doesn't receive one automatically, they should request one. If one is received but inadequate, with, for example, blank spaces that are not completed, they should request an appropriately completed one. Otherwise, if one is not produced with the appropriate information requested, the company should contact the local OSHA Area Office for assistance in obtaining the MSDS.

Copies of the MSDSs for hazardous chemicals in a work area are to be maintained in a file, retained for for 30 years in accordance with 29 CFR 1910.20 (d)(ii)(B), located close to workers, and readily accessible to them during each work shift. In some instances where employees work between workplace locations, MSDSs should be located centrally.

No specific format is mandated for MSDSs but they must contain certain items of information. The required information is shown in Table 2. The MSDS may contain more information; but it must contain what's shown in Table 2.

| MSDS CHECKLIST |
| --- |
| ◊ Identity of the chemical (as used on the label) |
| ◊ Physical hazards |
| ◊ Health hazards |
| ◊ Primary routes of entry |
| ◊ Whether the compound is a carcinogen |
| ◊ Precautions for safe handling and use |
| ◊ Emergency and first aid procedures |
| ◊ Date of preparation and latest revision |
| ◊ Name, address and telephone number of manufacturer, importer or other responsible party. |

Table 2. MSDS Check List

If any relevant information was not available at the time of preparation, the MSDS must indicate that no information was found.

## Employee Training Sessions

Employers are to establish a training and information program for employees who handle hazardous chemicals (section 1910.1200(h)). Training is the key to success and safety when employees deal with hazardous substances in the workplace (Table 3). Employee health and life depends on how effectively employees use a given company's training program. Such training should be provided at the time of initial assignment and whenever a new hazard is introduced into the work area. "Exposure" or "exposed" under the rule means that an employee is subjected to a hazardous chemical in the course of employment through any route of entry (e.g., inhalation, ingestion, skin contact, or absorption) and includes potential (e.g., accidental or possible) exposure. See paragraph (h) of the standard for specific requirements.

The standard specifies the information to be transmitted to employees and should also be workplace specific. They are to be informed of the requirements of this regulation, i.e., that it exists, that employers are required to have hazard communication programs,

and the components of the program at their workplace. Employees should also be informed of any operations in their work area where hazardous chemicals are present. They must also know where the employer will be keeping the written materials required under this standard, including the written hazard evaluating procedures, written program, lists of hazardous chemicals, and MSDSs required by this section.

**Minimum Training Requirements**

1. Methods or observations:
    a. detection of the presence or release
    b. detection of unsafe work practices
2. Physical and Health hazards
3. Measures of protection from hazards
    a. Work practices
    b. PPE
4. Details of employers Hazcom program
    a. Labels
    b. MSDSs

Table 3. Minimum Training Requirements

Employees must be trained regarding methods of observation they may use to detect the presence of a hazardous chemical in their work area, not just the hazards of the chemicals with which they work. Training includes measures that employees can take to protect themselves from the hazards and should include procedures to provide protection such as certain work practices and the use of personal protective equipment (OSHA #3077, 1995). The employer should also explain the hazard communication program implemented; to include how to read and interpret information on labels and MSDSs, and how to use the hazard information.

## The Written Plan

The written HazCom program must be available upon request and accessible to every employee. Any material related to training procedures used, chemical determination, chemical test methods should be included in the program. Written programs should reflect what the employer is doing in the workplace. Written HazCom records must contain (as per accordance with 1910.1200(e), (i) and (ii)), at a minimum, the following:

1. Procedures used to determine which chemicals are hazardous
2. List of hazardous chemicals used in each particular workplace
3. Methods used to comply with requirements for marking, training and information, including:
    a. Specific training write-up
    b. Instruction manual and employee handbook
    c. Samples of MSDSs and labels used
    d. Samples of posters/signs displaying employee rights
    e. Additional references used in training
4. Availability

For example, the written plan must list the chemicals present at the site, indicate who is responsible for the various aspects of the program at the facility, and indicate where written materials will be available to employees.

The written program must describe the requirements for labels and other forms of warning, material safety data sheets, and employee information and training. In addition, once an employee has completed the training program, the employee should be awarded a certificate of completion and a duplicate should be retained for future records. Although this is not required by OSHA, some feel that this helps employers better monitor their own programs to ensure that all employees are appropriately trained.

OSHA doesn't expect that every worker will be able to recite all of the information about each chemical in the workplace. In general, the most important aspects of training under the hazard communication program are to ensure that employees are aware that they are exposed to hazardous chemicals, and that they know how to read and use labels and material safety data sheets. Therefore, as a consequence of learning this information, they are following the appropriate protective measures established by the employer.

## Summary

Information and training are a critical part of the hazard communication program. Information regarding hazards and protective measures is provided to workers through written labels and material safety data sheets. However, through effective information and training, workers will learn to read and understand such information, determine how it can be obtained and used in their own workplaces, and understand the risks of exposure to the chemicals in their workplaces as well as the ways to protect themselves. A properly conducted training program and knowledgeable trainer (specialists) will ensure

comprehension, retention, and understanding. It is not sufficient to either just read material to the employees or simply hand them material to read. The educational atmosphere should be a climate where workers feel free to ask questions. This will help employers to ensure that the information is assimilated.

For any safety and health program, success depends on commitment at every level of the organization. This is particularly true for hazard communication, where success requires a change in behavior. This can only occur if employers understand the program, and are committed to its success. Specialists should be knowledgeable and experienced with OSHA's 29 CFR 1910.1200, and employees should be motivated by the people presenting the information to them. Remember, the underlying purpose of OSHA's hazard communication program is to reduce the incidence of chemical source illness and injury through better education and training of employees.

# CHAPTER III

## REVIEW OF THE RELATED LITERATURE

This study attempts to determine if mental modeling (MM) can be used as a diagnostic tool to assess the quality of specialists' knowledge. The Hazard Communication Standard, 29 CFR 1910.1200, will be used as the focal point to determine its understanding within a select and finite population in industry. More specifically, do the "specialists" have a firm understanding of OSHA's Hazard Communication Standard? Are these specialists conveying the required safety and health information to their employees? The related literature was reviewed with the following purposes in mind: (1) to review current uses of MM applications, (2) to assess the quality of specialists knowledge based on the findings in the MM study, and (3) to utilize the questionnaire as a measure to evaluate employee retention of their hazard communication program.

### Overview of Mental Modeling

One of the fastest growing applications of MM is research. Jungermann *et al* (1988) agree that, although awkward to work with at first, MM will be most valuable as tools and technology become more accessible. The MM approach, unlike other techniques, offers a perspective useful for analysis that takes human cognition into account. MM, a substitute for "knowledge," are naturally evolving models formulated by people. Although many of these models are often technically inaccurate, they are functional. Through constant interaction with the system, a person who continues to modify the mental model ultimately produces a workable result (Rouse and Morris, 1986).

MM is best suited for understanding how lay peoples' understanding of a complex phenomenon is perceived (Johnson-Laird, 1986). Often, these models are constrained by technical background, previous experience with similar systems, and the structure of the human information processing system. Gentner *et al* (1992) studied models, at least

those for understanding devices; however, most peoples' understanding was imprecisely specified, meager, and full of inconsistencies and gaps. Those models contained only partial descriptions of operations and large areas of uncertainty.

MM is a culmination of cognitive psychology, psychology related disciplines (e.g., linguistics, anthropology, and philosophy) and artificial intelligence. Cognitive psychology has expanded the range of techniques for investigating what is going on in the human mind. Artificial intelligence, on the other hand, allows explicit notations of theories of human knowledge information and processing. Therefore, an ideal mental model should be constructed by combining both lines of research and a researcher who is a knowledgeable practitioner of the domain being studied. In other words, Rouse *et al* (1986) state that, if studied correctly, mental models are synonymous with knowledge.

When considering a mental model, there are four things to be concerned with:

1. Target System, *t*
2. Conceptual model of the target system, C(*t*)
3. User's MM of *t*, M(*t*)
4. Experts conceptualization of that MM, C(M(*t*))

When modeling a person's mental model of a particular *target system* (*t*), we must already have in place a conceptual model of that system: called the conceptual model of *t*, C(*t*). The user's mental model of that target system is called M(*t*). Therefore, we can distinguish between C(M(*t*)) versus the actual model of that person, M(*t*). In other words, we assume that a person has gained some general knowledge about the domain. Moreover, the general conceptual knowledge guides the cognitive processing of information presented in some domain. Hence, when a person is educated or taught about a particular domain, *t*, specific knowledge is generated about this finite domain, M(*t*).

Gentner *et al* (1992) discuss three representational and functional factors that apply to M(*t*) and C(M(t)):

*Belief System* - a person's mental model reflects his or her beliefs about the physical system, which are acquired through observation, instruction, or inference. Therefore, a C(M(*t*)) should contain a model of all the relevant parts of the person's M(*t*).

*Observability* - there should be a correspondence between the parameters and states of the mental model that are accessible to the person as well as the aspects and states of the physical system that the person can observe. In the C(M(*t*)), there should also be a correspondence between parameters and observable states of C(M(*t*)) and the observable aspects and states of *t*.

*Predictive Power* - the purpose of a MM is to allow the person to understand and to predict the behavior of a physical system. Thus, a C(M($t$)) should comprise a model of all the relevant human information processing and knowledge structures that are needed for understanding and predicting the physical system.

MM is composed of three elements: describing, explaining and predicting. Combined, all three yield an integrated view of the actual purpose of MM. Figure 4 illustrates the overall purpose of MM, showing the relationship between the three elements along with the purpose, function, state, and form of MM.

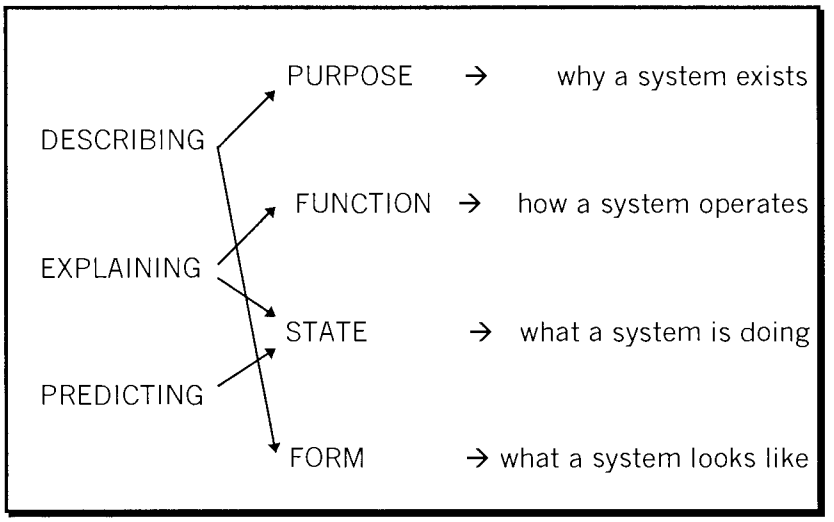



Figure 4. Purpose of Mental Modeling (Rouse and Morris, 1986)

Conceptual models are devised as tools for the understanding or teachings of physical systems. Mental models are the ideas which people have in their minds that will guide them when doing certain tasks. Depending upon the case, a direct and simple relationship between the conceptual and the actual mental model is often not the case. There should also exist a similarity between the parameters and states of one's model and their attempt to describe the model.

There are different kinds of models and conceptualizations. A C(M($t$)) generated should not be confused with the MM that a user originally created of a system, M($t$). Even the predicted C(M($t$)) may differ from the image that the system itself presents to the user. Only in an ideal world is the systems image (or target system) congruous with the designed conceptualization from the researcher's C(M($t$)).

*Influence diagrams* are used to construct knowledge maps allowing fragmented information to go from peoples' head to paper and onto a computer, ultimately capturing the relevant knowledge. These diagrams represent the possible actions a person may take and the information the person possessed when (s)he took the action(s). The development of influence diagram, in the form of relationships, provides a way to perform structural probabilistic assignments.

Each influence diagram is a directed network that represents the dependencies and events in a process. Nodes represent an event in this probabilistic process; each link represents a directed influence, showing the dependency of an event at the head of an arrow (Howard and Matheson, 1984). Often, influence diagrams are hierarchical in structure, with the bold nodes representing the basic events or concepts. Subdivisions are used to detail concepts of some higher level. Each influence represents a piece of the entire concept. Thus an influence diagram should capture the relationships needed to structure a decision, as well as to estimate its parameters (Howard, 1989). It is difficult for anyone to expect lay people to provide the details of an entire influence diagram. However, one would expect that the lay people should understand the important concepts and the directions of the influences in the diagram. Influence diagrams represent a knowledge structure, that is, a exposé of how knowledge about a particular topic is organized in the brain. If this is so, then a comparison between expert and non-expert diagrams can be used to design educational and communication programs that will reveal differences between expert and lay models

In summary, knowledge maps let you "say what you know and know what you say." By separating the issues of relevance from those of definition and numerical assessment, they permit gradual collection of knowledge in increasingly quantitative form. They allow people with expertise to communicate with each other in many different areas and to contribute their knowledge to solving problems.

## Advantages of Mental Modeling

The advantages to mental modeling are:

1. MM provides a good estimate of a knowledge domain
2. MM is an excellent tool to aid in education and training
3. MM is easily constructed for any domain

## Limitations of Mental Modeling

The disadvantages to mental modeling are:

1. Diagrams are incomplete
2. Peoples ability to "run" their models are limited
3. MM are unstable (e.g. people forget details especially when those details haven't been used for some time).
4. MM has no firm boundaries

## Introductory Example of Mental Modeling

An application of mental modeling (MM) is probed in the subsequent section which examines the misconceptions as well as the level of understanding of radon gas. This example provides a thorough stepwise construction and analysis of Bostrom *et al* (1992) which can be superimposed on the research conducted in this study. For a more in-depth look into MM and the research conducted by Bostrom *et al* (1992), please consult the article entitled "Characterizing Mental Models of Hazardous Processes: A Methodology and an Application to Radon."

Bostrom *et al* (1992) constructed a five stage strategy to tackle their problem. The five steps employed were:

(a) define the problem,
(b) create an expert influence diagram,
(c) elicit lay people's relevant beliefs,
(d) map those beliefs into the diagram,
(e) identify gaps and misconceptions.

Each step will be explored to show the fundamental concepts, usefulness, and reasoning behind MM.

1. Definition of the problem:

   Radon is a colorless, odorless gas that seeps into homes from the soil. The EPA estimates that between 7,000 and 30,000 lung cancer deaths per year in the United States may be attributed to radon exposure (Atman *et al*, 1994). The EPA recommends, for this reason, that all homeowners test their homes for radon and remediate if they find a concentration higher than 4 pCi/L. Homeowners need to know whether to test for radon, costs, the accuracy of the test, and the associated costs with remediation if radon is discovered to be potentially hazardous.

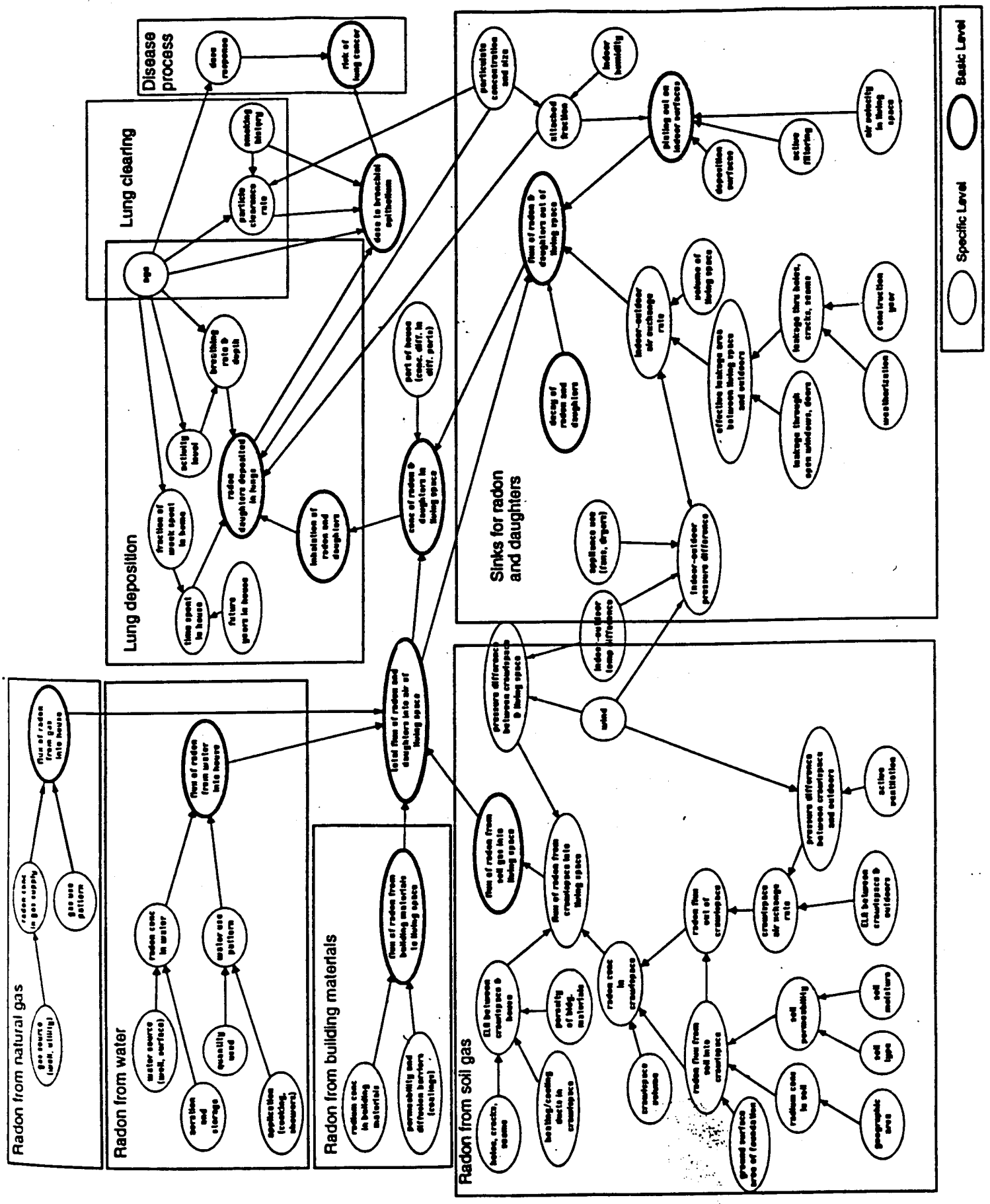



Figure 5. Expert influence diagram for radon risk in house with crawlspace

Therefore, the first task would be to determine what are the current beliefs about radon (e.g., how radon is produced, migrates to the human receptor, enters the receptor's body, and produces harm such as lung cancer).

Bostrom *et al* use MM to examine this problem. Through an open-ended interview consisting of two discrete stages, an expert influence diagram is used to determine the level of "misconceptions" or "ignorance" that exists about current beliefs on radon.

2. Construct an expert influence diagram

The influence diagram was constructed by several researchers for the decision-relevant information regarding radon, for a typical homeowner (Figure 5). The influence diagram is hierarchical in structure and contains 14 first-level concepts, and 48 more specific concepts. It is a directed network that represents the dependencies and events in a process.

On the left and across the bottom are factors that influence radon exposure processes. Health effect processes, in the upper right-hand corner, include the end point of this directed network --- the risk of lung cancer from indoor radon. Each node represents an event in this probabilistic process whereas each link represents a directed influence.

3. Elicit lay people's relevant beliefs

A diverse set of twenty-four participants were interviewed, taped and transcribed by a single researcher who was specialized in communicating occupational hazards. Each respondent was interviewed in a two stage open-ended interview allowing the respondents to explore their beliefs on radon in more detail, thus characterizing lay perceptions. In the non-directive stage, the respondents were asked to describe everything there is to know about radon and its risks. Once the area was exhausted, respondents were asked to elaborate on each comment that they had made.

In the second stage of the interview, the directive stage, respondents sorted thirty-six photographs (e.g., a diagram of a lung, person dusting a bookshelf, and a frozen food section at a grocery store) according to whether they had something to

do with radon. The purpose of the photos was intended to increase the chances of evoking untapped beliefs with a greater risk of reactivity.

4. Map those beliefs into the diagram

The transcripts were coded into the expert influence diagram and those that didn't fit were sorted and listed into five types: (a) wrong concepts; (b) peripheral beliefs, correct but not central to the problem (e.g., radon from industrial waste); (c ) indiscriminate beliefs, correct but imprecise (e.g., "radon makes people ill" where illness was not clarified); (d) background beliefs (e.g., "radon is a gas"); and (e) valuations, such as "radon is dangerous."

Along with the 14-first level concepts and 48 specific concepts, respondents contributed 6 background concepts, 6 peripheral concepts, 20 indiscriminate concepts, 16 erroneous concepts, and 4 valuation concepts, for a total of 114 different concepts.

5. Identify gaps and misconceptions

The result of this study produced statistical summaries for the frequency of specific beliefs and for several aggregate properties of responses (e.g., completeness, accuracy, and specificity). The statistics identified that respondents knew relatively few of the facts in the influence diagram, with the known facts concentrated at the highest level of generality and combined with a substantial admixture of nonexpert concepts. The results suggest that people like these respondents have a good deal to learn (and unlearn) before they would understand the basic structure of the radon problem.

| | Nondirective phase | | | Directive phase | | |
|---|---|---|---|---|---|---|
| Measures | All concepts | Exposure concepts | Effects concepts | All concepts | Exposure concepts | Effects concepts |
| *Completeness* | | | | | | |
| All levels | 0.11 | 0.12 | 0.05 | 0.11 | 0.12 | 0.1 |
| Level 1 | 0.18 | 0.21 | 0.08 | 0.22 | 0.24 | 0.17 |
| *Accuracy* | | | | | | |
| All levels | 0.06 | 0.09 | 0.03 | 0.06 | 0.09 | 0.04 |
| Level 1 | 0.03 | 0.16 | 0.05 | 0.05 | 0.16 | 0.06 |

Table 4. Mean Proportions obtained by Respondents on Various Measures of Performance

On the average, respondents produced 14 concepts in the non-directive portion of the interview and 15 concepts in the directive portion. Three statistical measures of the extent of the lay peoples' knowledge about radon were defined: completeness, accuracy, and specificity. These measures measured how much the respondents knew, what proportion of their beliefs were correct, and how much detail those beliefs were.

| | Number of respondents mentioning concept | | | Proportion of respondents |
|---|---|---|---|---|
| Concept | Nondirective phase only | Directive phase only | Both | mentioning at least once |
| *Exposure level 1* | | | | |
| Concentration of radon in living space | 1 | 0 | 21 | 0.92 |
| Total flux of radon into living space | 4 | 2 | 12 | 0.75 |
| Efflux of radon from living space | 2 | 9 | 0 | 0.46 |
| Radon from water | 0 | 5 | 2 | 0.29 |
| Radon from soil gas | 2 | 1 | 3 | 0.25 |
| *Exposure level 2* | | | | |
| Part of house (conc. differs in house) | 11 | 0 | 6 | 0.71 |
| Geographic area | 15 | 1 | 1 | 0.71 |
| Pipes/ducts going into house from ground | 2 | 10 | 4 | 0.67 |
| Holes, cracks, and seams | 1 | 7 | 6 | 0.58 |
| Radon influx to basement/crawl space | 4 | 2 | 8 | 0.58 |
| Leakage through open windows/doors | 2 | 7 | 2 | 0.46 |
| Indoor-outdoor air exchange rate | 1 | 0 | 6 | 0.29 |
| Appliance use (fans, dryers) | 0 | 5 | 1 | 0.25 |
| Construction of building | 3 | 2 | 1 | 0.25 |
| *Effects level 1* | | | | |
| Inhalation of radon | 1 | 9 | 3 | 0.54 |
| Lung cancer | 1 | 1 | 3 | 0.21 |
| *Effects level 2* | | | | |
| Smoking history | 1 | 3 | 1 | 0.21 |

Table 5. Frequency of Mention of Expert Concepts by Respondents

Table 5 and 6 show the frequency with which concept in the expert influence diagram was mentioned by the respondents and the frequency with which different kinds of non-expert concepts were mentioned, respectively.

| Affects plants | Number of respondents mentioning concept: Nondirective phase only | Directive phase only | Both | Proportion of respondents mentioning at least once |
|---|---|---|---|---|
| *Background* | | | | |
| Radon is detectable with a test kit | 19 | 0 | 4 | 0.96 |
| Radon is a gas | 4 | 3 | 14 | 0.88 |
| Radon is radioactive | 1 | 0 | 7 | 0.33 |
| *Phenpheral* | | | | |
| Mining/radon from mines | 3 | 6 | 1 | 0.42 |
| Affects animals | 0 | 8 | 0 | 0.33 |
| *Indiscriminate* | | | | |
| Radon from underground | 4 | 1 | 15 | 0.83 |
| Radon attaches to dust | 0 | 7 | 0 | 0.29 |
| Radon is environment | 2 | 3 | 0 | 0.21 |
| Fans (ventilation) | 0 | 7 | 3 | 0.42 |
| More lower in house | 7 | 0 | 3 | 0.42 |
| Cancer | 6 | 3 | 6 | 0.63 |
| Lung problems | 0 | 10 | 1 | 0.46 |
| Affects plants | 4 | 2 | 0 | 0.25 |
| Affects plants | 0 | 6 | 0 | 0.25 |
| *Erroneous* | | | | |
| Affects plants | 1 | 13 | 0 | 0.58 |
| Affects plants | 0 | 7 | 0 | 0.29 |
| Contaminates water | 0 | 5 | 0 | 0.21 |
| Contaminates blood | 0 | 9 | 0 | 0.38 |
| Radon from garbage | 1 | 4 | 0 | 0.21 |
| *Valuation* | | | | |
| Radon is risky, dangerous | 4 | 3 | 6 | 0.54 |

Table 6. Frequency of Mention of Non-expert Concepts by Respondents

The results of the interviews indicated that, at a minimum, communicating the risks associated with radon should include: (a) no way to tell if radon is present without testing, (b) how to test for radon, (c ) how remediation is accomplished, and (d) that radon decays in a few days.

## Current Applications and the Role of Mental Modeling in Occupational Health and Safety

Currently, after an exhaustive literature review, there is no published research which uses MM as a diagnostic tool to determine specialists knowledge in an industrial setting. Many of the models created were to specifically quantify a characteristic phenomenon (e.g., communicating risks to people who take over-the-counter drugs and informing and educating people about radon gas). MM is still in its infancy and there is enormous potential for its applications that remains to be explored. To date, there has been no mention of using MM to evaluate the knowledge of specialists within an established educational and training program.

## Status of Qualified Personnel-"Specialists"

There are numerous safety officials and managers who handle ERTK training and retraining of personnel at almost every non-governmental industry throughout the United States. Most of the training can be in-house by a trained or experienced individual. Some trainers can be sought through a specialty company suited for just that -- teaching hazard communication. Other qualified personnel are those directly related to the Department of Labor including safety inspectors whose primary purpose is to enforce the requirements set by OSHA.

The label "specialists" has been fixed with a minimum of 5 years of ERTK experience. This provides the specialists with enough background to have a thorough understanding of the regulation, 29 CFR 1910.1200.

## Summary

This chapter has presented a brief overview of MM and how applicable this method is in determining areas of "ignorance or confusion," "deficiencies," or "misunderstandings". The search for mental models is of great importance and any success that is achieved is likely to have substantial impacts on system design and instruction. An example utilizing MM was outlined in this chapter showing the necessary steps to complete a MM study.

# CHAPTER IV

## RESEARCH DESIGN AND PROCEDURES

The following steps were used in researching the problem, planning the study to include *mental modeling* (MM) and survey methods, conducting the study, and formulating and presenting the results.

1. Review of the related literature
2. Construct regulatory expert MM diagram based on 29 CFR 1910.1200
3. Elicit "specialists" relevant beliefs on the standard
4. Identify gaps and misconceptions
5. Develop research questionnaire
6. Preparation of cover letters and thank you letters
7. Pre-testing the research questionnaire
8. Selection of the population
9. Data collection
10. Analysis and interpretation of data
11. Presentation of conclusions and recommendations

This study is a designed to determine if MM can be used as a diagnostic tool to assess *local specialists* knowledge. Data from a select group of companies concerning their knowledge and implementation of hazard communication was solicited. This data was obtained from both the specialist and their respective employees in regards to their current work practices and knowledge of OSHA's *Hazard Communication* standard (29 CFR 1910.1200; Appendix A).

## The Data

The study consists of a regulatory expert MM diagram and a research questionnaire for collaboration. Each tool was constructed with the Hazard Communication (HazCom) standard as the primary framework.

The expert influence diagram, or regulatory expert mental model, was constructed based on the HazCom standard (Chapter IV). Upon completion, local specialists at each company were interviewed extensively in an open-ended format with their consent (as mandated by Oklahoma State University's Institutional Review Board (IRB); the IRB MM consent form can be found in Appendix H). Their lay models were used to show discrepancies, if they existed, between the expert, the regulation, and their knowledge of the *Employee Right-to-Know* (ERTK) standard.

The collaborative ERTK questionnaire was provided to respective employees at each company involved in the study. The questionnaire included a cover/consent letter stating that the survey was completely voluntary, and complete anonymity was maintained (as mandated by Oklahoma State University's IRB; the IRB ERTK questionnaire can be found in Appendix H). Questions ranging from hazard communication, personal protective equipment, in-house safety evaluation, and a 10 question multiple-choice examination on ERTK was administered. The questionnaire was designed to probe their knowledge of ERTK as mandated by OSHA. Special consideration was also given to the format of the survey to increase the response rate. A laser printer, colored paper, and variable type and font titles were used to produce a quality and reproducible questionnaire.

The responses for both studies were coded and entered into a data set. Specialist's views were overlaid onto the regulatory expert mental model to reveal misconceptions, ignorance, or confusion about the ERTK standard as it pertains to informing and training employees.

Statistical analysis was performed on the questionnaire to tabulate the responses and to reveal percentages or averages and deviations for each response on the questionnaire.

The results of this study, coupled with the questionnaire research, attempted to show a training effectiveness of ERTK implemented in the workplace at each company. The MM study was evaluated as a diagnostic tool, based upon the HazCom standard, to assess local specialists' knowledge.

## The Criteria for the Admissibility of the Data

The project does contain standardized features with regards to designing and planning this research project. They are universality, replication, control and measurement (Leedy, 1993). Thus, this project could be completed by any person or persons having a thorough knowledge of hazard communication and of MM wishing to justify or modify the research objective.

Local specialists, an appointed safety officer or manager with a minimum of 5 years experience in ERTK program management, were questioned on their relevant knowledge and beliefs of the ERTK standard and methods employed in the workplace. Specialists who did not meet this criteria were not involved in the study.

An ERTK questionnaire was also provided to each company involved in the research effort who must have, by law, a hazard communication program in place as mandated by the standard. Responses that were filled out accurately and completely were kept and used in the analysis. Employees that didn't respond did not have a second chance and were not factored into the total number of responses.

## The Research Methodology - *The ERTK Questionnaire*

The research methodology is primarily that of qualitative research. In order to design an applicable questionnaire there are several steps that must be accomplished prior to its testing. These are:

1. Review literature relating to questionnaire design
2. Analyze sample questionnaires (Warde, 1996)
3. Consult faculty and safety personnel (specialists) for validation or additions
4. Revising draft questionnaire
5. Pre-testing questionnaire

To encourage a higher response rate, the questionnaire was designed in a straight-forward, easy-to-answer format. The questions were designed to be as clear, specific, and concise as possible.

## Survey of Related Literature

The available professional publications and literature relating to MM applications were examined to determine if similar studies had been made. A review of the literature concerning the use of MM in industry was also examined. Sources revealed, that although MM has been used for complex systems, it has not been used in an industrial setting.

The review of literature was helpful and informative. However, there were no studies found and/or published at this time dealing with the use of mental models as a diagnostic tool to assess specialists command of a knowledge domain.

## Development of the Regulatory Expert Mental Modeling Diagram

The regulatory expert mental model was based on the information provided by the HazCom standard. The expert model was assembled and structured to facilitate construction and ease of use in the open-ended interviewing process. The ERTK standard is very long, complex, and detailed; a model of this type has never been attempted or documented in the literature using MM approach. This new exploratory regulatory expert mental model of 29 CFR 1910.1200 subpart Z was constructed and assembled.

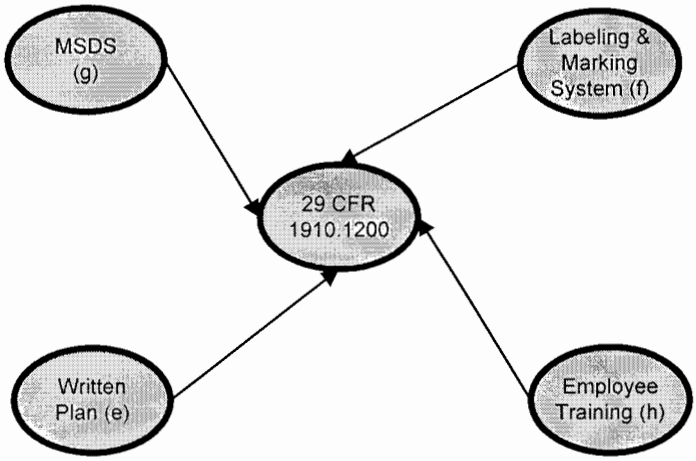



Figure 6: Quadrant Representation of 29 CFR 1910.1200

This particular expert model is divided into HazCom's four basic components or quadrants. Figure 6 represents one possible approach to utilize MM, illustrated with OSHA's HazCom standard. These respective quadrants are the written plan, Material Safety Data Sheets (MSDS), labeling and marking system, and employee training. Each quadrant surrounds the central regulation, 29 CFR 1910.1200. Each node is bold

because it is a major component within the standard. It is this essential "expert" knowledge that comprises the HazCom standard.

The simplistic quadrant-like representational diagram above is also called an *influence diagram* where each node-link-node combination portrays a directed influence. When completely specified, an influence would be in terms of conditional probabilities, where *a influences b, b influences* c, and so forth. This regulatory expert model can be seen as an influence diagram because within the regulations, a section or sections may include a statement(s) that relate a particular section to other federal regulatory titles, subparts, or sections. Moreover, influences may arise from interactions within the standard, such as (Figure 7):

- The written plan is composed of the labeling and marking system, MSDS, employee training, and the written plan itself;
- Training of employees in HazCom consists of MSDS, labeling and marking system, ERTK (i.e. awareness of the ERTK standard and its requirements) and the written plan; etc.

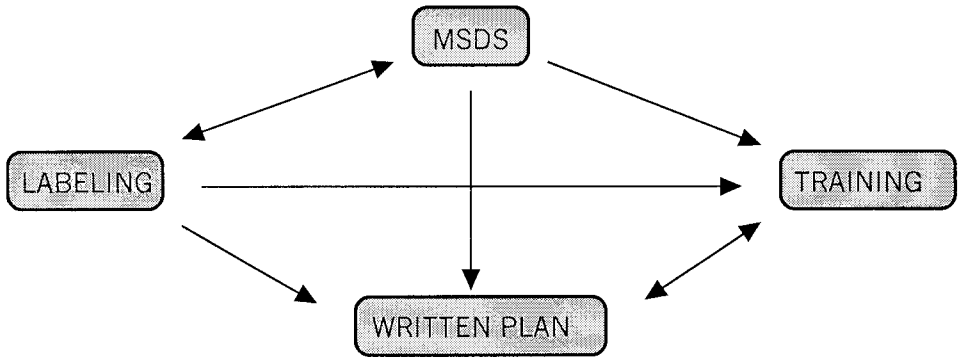



Figure 7. Basic HazCom Concepts and Their Influences

Given that complex hierarchical influences exist (i.e. cross linkages between sub-components and other neighboring quadrants), they would significantly affect the diagram's understandibility and the focus of the research project. Therefore, influences remain basic and central to each node or quadrant, so, information is presented pictorially and individualistically as to not distract from the theme or scope of the project. These influences are expanded into their respective sub-components in Appendix C, D, E, and F for MSDS, labeling and marking system, the written plan and employee training, respectively.

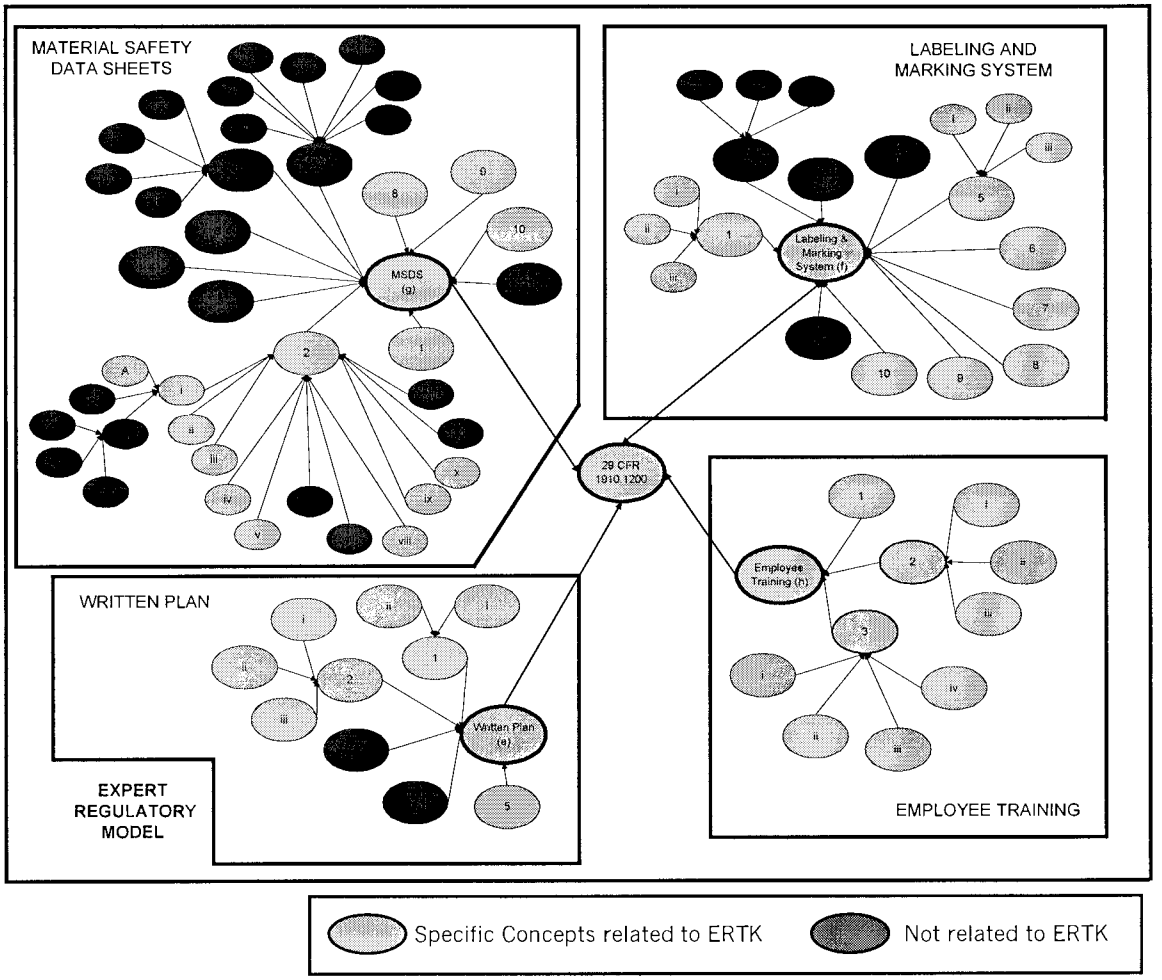



Figure 8. Regulatory Expert Mental Model

When each quadrant is expanded into its sub-components, the overall diagram takes on a hierarchical structure (Figure 8; Appendix B). Within each quadrant, there are up to five levels of detail in each concept whose values in turn could influence the states of some higher level concept. Those higher level concepts are referred to as secondary, tertiary, quaternary, and pentenary influences of HazCom (Table 7). Influences which represent an opportunity to inform and train employees about those chemical hazards in the workplace, as mandated by the ERTK standard, are *gray* nodes. All other nodes are darkened and are not relevant to training employees [These nodes are designed with either the manufacturers or company's intent to maintain compliance with the ERTK standard (e.g. suppliers of MSDS or labels with hazardous material, etc.)].

| Quadrant: | Total Relevant | Number of Concepts | | | |
|---|---|---|---|---|---|
| | | *General* | | *Specific* | |
| | | Secondary | Tertiary | Quaternary | Pentenary |
| Material Safety Data Sheets | 14 | 11 | 23 | 3 | 3 |
| Labeling & Marking System | 13 | 11 | 3 | - | - |
| Written Plan | 8 | 5 | 5 | - | - |
| Employee Training | 10 | 3 | 7 | - | - |

Table 7. Concepts per Quadrant of Regulatory Expert Mental Model

This influence diagram, pictured above, captures the relationships required to structure a decision, as well as to estimate its parameters. Each quadrant can be expanded in further detail identifying the significance of each component and sub-component; as pictured below for employee training (Figure 9). In each quadrant in this study, all influences are directed toward each central node and is indicates which concepts are significant to employee training (gray nodes).

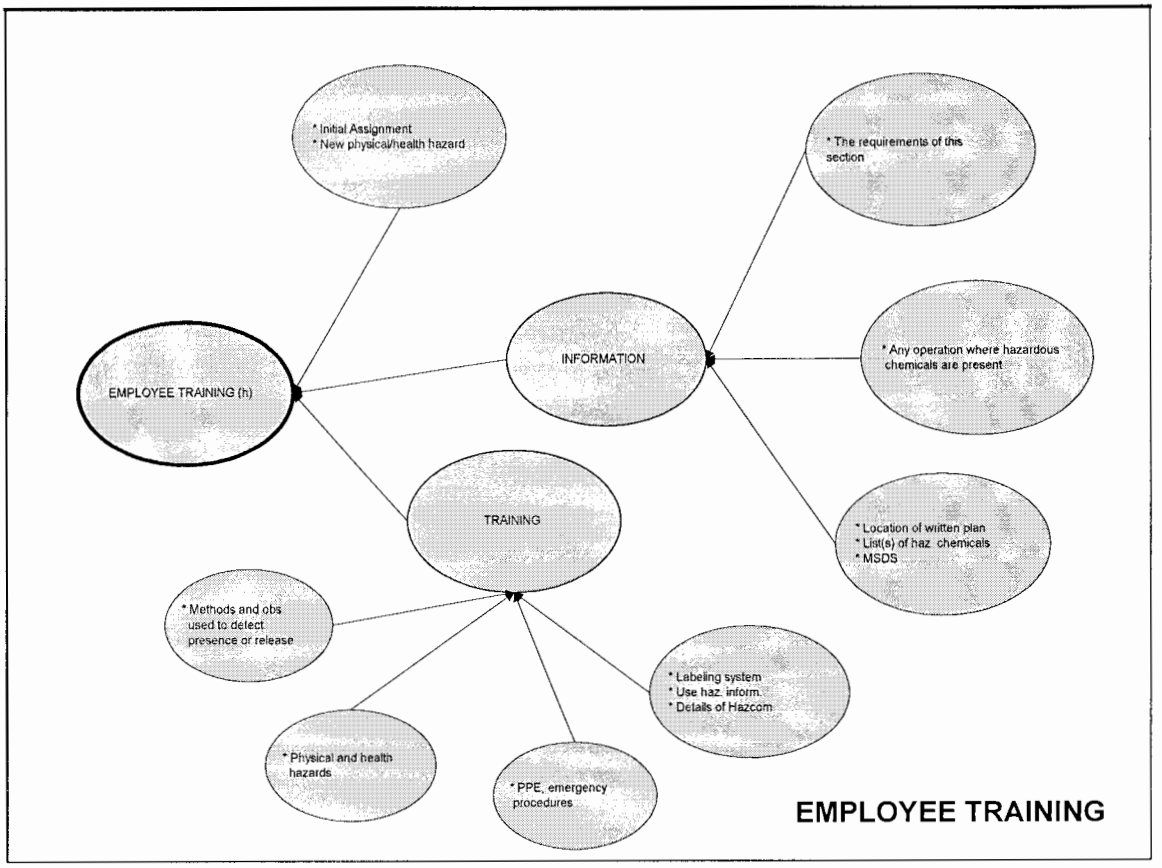



Figure 9. Regulatory Expert Model of Employee Training

It should be noted once again that an expert mental model of this type has never been documented publicly to assess specialists knowledge. This unique and novel expert mental model is the first such documented, and is designed to explore and assess specialists knowledge. In addition, this particular mental model, based on the ERTK standard, allows the processing and assimilation of open-ended interviewing specialists data to be simplified and focused on the relevant knowledge of the expert.

## Development of the Research Questionnaire

The research instrument, designed to gather data for this study, was a two-page ERTK questionnaire. After thoroughly reviewing literature related to questionnaire design, analysis of numerous sample questionnaires, and consultation with various researchers, the completed questionnaire was printed (Warde, 1996).

The questionnaire, designed by the researcher, went through several revisions as it was reviewed and critiqued by each safety officer at each participating company in this study and thesis advisor, Dr. Wayne Turner, and committee member, Dr. Will Focht, at Oklahoma State University. This consultation and evaluation indicated a need for minor clarifications on specific items and choice of questioning. Every effort was made to develop a questionnaire that was easy to follow and complete. More importantly, each question was designed to be stated clearly and not ambiguous. The questionnaire was also designed to be completed by the respondent in approximately 5 minutes.

The final instrument was a printed two-page, 8 1/2-by 11-inch questionnaire (Appendix G). It was printed on colored paper in an effort to increase the response rate. To protect the anonymity of the respondents, as required by Oklahoma State University's Institutional Review Board, the questionnaire did not require a signature, identity of participant, or name of the company. However, each group of questionnaires were analyzed individually by each respective company; the final results representing an overall retention of ERTK regulation implemented in each company.

The questionnaire encompassed the following five sections:

I. Personal Information
II. Hazard Communication Knowledge
III. In-House Safety Evaluation
IV. Personal Protective Equipment
V. Hazard Communication Exam

Section I of the questionnaire sought the title or job description of the employee, and length of employment with current employer.

Section II of the questionnaire was designed to obtain a profile of the employee in their environment and general knowledge of the HazCom standard. More specifically, the questions concerned previous training in ERTK, work related hazards, the written plan, and knowledge of Material Safety Data Sheets.

Section III of the questionnaire aimed at determining the employees perspective of current safety work practices implemented in their environment and by their company's safety officer/manager.

Section IV of the questionnaire focused on personal protective equipment (PPE). It's purpose was to show safety officials their general knowledge of PPE, its limitations, and level of protection their PPE provides against dangerous substances.

Section V consisted of 10 multiple choice questions concered with basic concepts or ideas that pertain to employee training in hazard communication. Knowledge of the ERTK standard included definitions (e.g., carcinogen, physical hazard, acute vs. chronic), material safety data sheets, the written plan, the labeling system, and training.

To expedite completion thereby encouraging response, the survey instrument was designed in a straight-forward, easy-to-answer format. Related to the purpose of the study, the questions were formulated to be as clear, specific, and concise as possible. In developing the questionnaire for reliability and attractiveness, clear and complete directions were included, along with a title reflecting the purpose of the study, as well as varying type style and size for headings, and professional quality reproduction.

## Preparation of Various Letters and Forms

The consent letter, required by the IRB, was carefully constructed in order to encourage the participant to partake in either study (Appendix H). It was continually stressed that participation was voluntary and that the identity of the participant and company would remain anonymous.

Cover letters were provided to all safety officers to instruct them on how to distribute and then collect the completed questionnaires. The letters were written in the format and style of a business letter and were concise yet explanatory. It contained encouragement for the company(s) to participate in the study by providing the ERTK questionnaires to their respective employees. These letters were reproduced on the School of Industrial Engineering and Management, Oklahoma State University stationery.

The acknowledgment letter was to express gratitude for participating in the study. Enclosed along with the letter, an abstract of the results was provided to each company with the overall statistics of the participating companies involved in the study. This follow-up letter was also reproduced on School of Industrial Engineering and Management, Oklahoma State University stationery.

## Selection of the Population

In the early planning stages of this study, a decision was made to survey many safety officers/managers (e.g. specialists) and their employees at a variety of companies with an established ERTK program. The population and size of study was decreased due to the complexity and the amount of data generated. Moreover, each company was selected based on geographical location. Each company had a sincere interest in improving their knowledge and the knowledge of their employees.

## Collection of the Data

### MENTAL MODELING

Three interviews were conducted individually at each participating company by a single interviewer, a regulatory expert, with the typical interview lasting one hour. Each specialist was provided a pen/pencil and paper to jot down their thoughts. With consent, each interview was recorded with a miniature cassette recorder.

The local specialists identified their background and training experience related to ERTK training. Each respondent was then queried about their knowledge of the HazCom standard as it pertains to informing and training employees. Once their spontaneous responses appeared exhausted, respondents were asked to elaborate on each comment that they had made to probe deeper into their knowledge of the ERTK Standard.

### QUESTIONNAIRE

The survey instruments and cover letters were hand delivered to each company, thereby promoting an increase in participation due to a scheduled deadline, and an efficient and higher response rate (Table 8). Approximately 1 week after the original drop-off, telephone contact was made with each safety officer/manager to determine if the time

frame required for completion needed to be extended. Several companies opted to extend the scheduled deadline due to extraneous circumstances.

| Company | No. Surveyed | No. Returned | Response Rate |
|---|---|---|---|
| A | 150 | 92 | 60% |
| B | 100 | 37 | 37% |
| C | 100 | 58 | 57% |

Table 8. Response Rate of Companies

After all responses were collected, sorted, eliminated, and entered into a data base, company A, B, and C had a response rate of 60, 37, and 57 percent, respectively.

## Analysis and Interpretation of the Data

MENTAL MODELING

All interviews were taped and transcribed with permission from each specialist. After being checked for accuracy by the interviewer, the transcripts were coded onto the regulatory expert influence diagram separately for each specialist (Chapter V). Concepts that did not fit onto the diagram were listed separately, and sorted into two categories:

(a) *peripheral beliefs*, correct, but not relevant to informing and training employees according to the ERTK standard,

and

(b) *indiscriminate beliefs*, correct, but not precise.

The tabulation of the data collected is shown in table form in Chapter V. The interpretation of the tabulated data is also reported in Chapter V.

QUESTIONNAIRE

After the completed questionnaires were returned, the responses were coded and entered into a data set. Statistics were used to tabulate the responses from each questionnaire and to reveal the percentages or averages as well as deviations of each response to each question (Malec, 1993). The tabulation of the data collected is shown in table form for all five sections on the questionnaire in Chapter V. The interpretation of the tabulated data resulted in the findings which are also reported in Chapter V.

## Presentation of Conclusions and Recommendations

On the basis of the findings reported in Chapter V, conclusions and recommendations were made which are included in Chapter VI.

## Summary

This chapter has described the steps used in researching the problem, planning the study, conducting the survey and presenting the results of the study.

The MM study involved a regulatory expert model based on OSHA's HazCom standard. It was constructed to facilitate the interviewing process and to be used as a training tool for the specialists concerning the regulatory information. The model was also used to query the knowledge of each local specialist trained in disseminating hazard communication to employees at their company. Each specialist was questioned about their knowledge of the ERTK standard and what employees are required to know. An attempt was then made to determine if MM, using the regulatory expert mental model, can be used as a diagnostic tool to assess their knowledge of the standard.

The questionnaire, used in collaboration with the MM study, was administered to each company. The questionnaire covered many areas of hazard communication including MSDS, PPE, training procedures, the labeling and marking system, and an employee evaluation of their company's safety program. Several steps were taken to increase the response rate: formulation of a good questionnaire, selection of an appropriate population, and the development of an appealing cover/consent letter to encourage participation. These steps have resulted in obtaining a higher response rate, thereby contributing to a more valid, reliable study.

# CHAPTER V

## ANALYSIS AND INTERPRETATION OF THE DATA

The *mental modeling* (MM) study was developed using OSHA's *Hazard Communication standard,* 29 CFR 1910.1200 subpart Z, as the expert (Appendix A). The study is designed to analyze MM as a diagnostic tool to assess the command of experienced *specialists* of the standard as it pertains to employee training and informing. Three safety trainers, local specialists in Oklahoma, were thoroughly examined to compare their knowledge of the Hazard Communication (HazCom) standard to that of the expert. Each respondent was queried about their knowledge, and their appropriate beliefs were then mapped onto the expert *influence diagram.*

A collaborative research questionnaire was administered to employees of all three companies as well. The data gathered, centered around the dissemination and retention of the HazCom standard used by their employees. The findings resulted from a detailed analysis of responses to the questionnaire.

### Method of Analyzing the Data

#### MENTAL MODELING

Figure 8, Chapter IV, represents a novel approach to MM, where an influence diagram of this nature uses a node-link-node combination, which portrays a guided or directed influence. The regulatory expert influence diagram has four primary areas, or quadrants, associated with the HazCom standard. These relevant and essential *Employee Right-to-Know* (ERTK) quadrants can be broken down into its respective components which ultimately comprise the standard. The four components are *Material Safety Data Sheets* (MSDS), employee training, written plan, and the labeling and marking system.

All four quadrants are applicable to informing and training employees, which will be used to measure local specialists knowledge. Each concept (i.e. node) relevant to ERTK are identified as gray ovals. On the other hand, those areas or concepts which are not

relevant to training are signified in the diagram as darkened ovals; these sections are designed primarily as a manufacturers' or industries' guide for compliance with the OSHA ERTK standard.

The most important point that should be noted is that an influence diagram of this nature captures the relationships required to structure a decision, as well as to estimate its parameters. This regulatory expert model has a hierarchical structure where there are up to five levels of detail in the concepts whose values could influence the states of some higher level concept. Those higher level concepts are the primary influences of HazCom whereby each influence represents an opportunity to inform employees about those chemical hazards in the workplace.

## QUESTIONNAIRE

The questionnaire, Appendix G, is divided into five sections, as follows:

I. Employee Profile
II. General HazCom Knowledge
III. In-House Safety Evaluation
IV. Personal Protective Equipment
V. ERTK Multiple Choice Examination

The first section, Section I, is divided into two areas: job title and length of employment with current employer. Only length of employment will be analyzed using averages and standard deviations. Research on specific employee job function and its results may be performed by the company with the aid of the appendix data.

Section II determines the employee's general knowledge of the hazard communication standard and their perception of the chemical hazards in their environment. Each area was analyzed using either averages and standard deviations or percentages.

The third section allows employees to provide feedback to the employer by rating the company's overall concern for safety and their willingness to notify of any unsafe work practices. Each area was analyzed using averages and standard deviations or percentages.

The fourth section, analysis of personal protective equipment used on the job, tries to determine if employees supply their own equipment, know their limitations, and know how to wear them effectively. Each area was analyzed using averages and standard deviations or percentages.

Section V determines what specific knowledge or concepts they know about the HazCom standard through a multiple-choice 10 question examination. Each area was analyzed using percentages or averages and standard deviations for each company.

Statistics were utilized to tabulate the responses of each item in the questionnaire; each grouped by section. The results from each response are presented in tabular form according to the average and standard deviation or percentage for each question. The specific results of the findings may be seen in the various tables in the following discussion and in Appendix I, J, and K.

## Data Analysis of the Mental Model

Each specialist met the stated definition of HazCom "trainer", or specialist, as defined in Chapter IV. They were a diverse set of individuals with a variety of experiences and backgrounds but no claim is made about their representativeness.

All three local specialists were interviewed at their respective company in Oklahoma by a single interviewer. The interviewer, an expert in the OSHA regulations, queried each specialist about their knowledge of the standard as it pertains to employee training and informing.

All interviews were transcribed and taped with permission from each specialist. After being checked for accuracy by the interviewer, the transcripts were coded onto the expert influence diagram providing equal weight for each concept missed or mentioned. Those concepts that did not fit either into the diagram or were irrelevant to training were listed separately and sorted into two categories: (a) *peripheral beliefs*, correct, but not particularly relevant to the ERTK standard; and (b) *indiscriminate beliefs*, correct but imprecise.

The regulatory expert influence diagram (Figure 8, Chapter IV), based on OSHA's ERTK standard, contained a total of 45 concepts relevant to employee ERTK training. In addition, respondents contributed 5 peripheral concepts, and 10 indiscriminate concepts, for a total of 60 different concepts. (See Table 14 for a complete list of those non-expert concepts.)

On the average, specialists produced 40 concepts in the interview. Three statistical measures, Table 9, of the extent of specialists' knowledge about HazCom were defined: completeness, accuracy, and specificity. Each statistical measure determined how much they knew, what proportion of their beliefs were correct, and how detailed or general those beliefs were. Each concept was assumed to be equally important to

employee training as well as any other concept related to the OSHA citation. Therefore, equal weights for each concept will be used in the analysis to measure the extent of each specialist's knowledge relative the standard.

The first measure, *completeness*, was computed as the percentage of the concepts in the expert model that a given lay model included. On average, specialists produced 47% of the total expert model in the interview. As might be expected, the level of completeness was much higher for the training and labeling concepts because they are essential to employee training and are two vital components to the standard.

Training typically focuses more on the labeling and marking system more than any other ERTK concept because employees have more hands-on contact with those hazards than any other form of warning (i.e. MSDS). Perhaps less predictable was the higher level of completeness for the written plan concept compared to MSDS concepts. This is probably because there are more concepts for MSDS than any other concept combined. Consequently, it is almost impossible for a specialists, regardless of training, to remember everything on an MSDS without consultation.

| Measures | All concepts | MSDS concepts | Labeling concepts | Written Plan concepts | Training concepts |
|---|---|---|---|---|---|
| *Completeness* | | | | | |
| All levels | 0.47 | 0.32 | 0.39 | 0.51 | 0.84 |
| *Accuracy* | | | | | |
| Related to ERTK | 0.69 | 0.66 | 0.59 | 0.51 | 0.84 |

Table 9. Mean Proportion on Various ERTK Concepts Obtained by Specialist concerning 29 CFR 1910.1200

Within this study, there are several possible ways to measure the accuracy of those concepts that the specialists did mention. *Concurrence*, a measure of the percent of expert concepts that appeared in the expert model, found that the specialists knew 66, 59, 60, and 84% for each quadrant of the model for MSDS, labeling, written plan, and training, respectively, with an overall accuracy of 69% (Table 9). *Accuracy* provides a more comprehensive overview, providing credit to specialists who not only said primarily right things, but also listed more of them. It was observed that the specialists were equally accurate in all four quadrants, yet, more accurate about the important, training and labeling concepts. Furthermore, specialists were more accurate about MSDS expert concepts than written plan concepts.

The final measure, *specificity*, was calculated as the ratio of specific concepts to more important general concepts in each respondents data. Thus, a ratio larger than 1 meant that the specialist had a higher proportion of specific concepts than the expert

model. This calculation considered only concepts that were in the expert model and relevant to training, because other concepts were either not specified by the regulation or not known knowledge of the expert. The mean ratio was 0.71 for the interview. Thus, specialists were much more general than the expert. Specialists who provided more concepts were only slightly more specific, meaning that saying more was nearly as likely to increase the breadth of coverage as its depth or specificity. Providing more concepts was associated with providing more detailed non-expert concepts. These additional concepts were not necessarily wrong, but added additional coverage to support the standard.

| 29 CFR 1910.1200 | Regulatory Abstract/section | Company A | B | C |
|---|---|---|---|---|
| g) | **Material Safety Data Sheets** | x | x | x |
| 1 | MSDS in the workplace for each haz. chem. they use | x | x | o |
| 2 | Each MSDS must be in English | o | o | o |
| I | Identity as used on the label | x | x | o |
| A | If single substance, its chem. and common name(s) | o | o | o |
| ii | Physical and chem. char. of haz. chem. | xx | xx | xx |
| iii | Health hazards | x | x | x |
| iv | Primary routes of entry | o | o | o |
| viii | Precautions for safe handling and use | x | x | x |
| ix | General control measures (PPE) | x | x | x |
| x | Emergency and First aid procedures | x | x | x |
| 8 | Copies of MSDS for each chem., readily accessible | x | x | o |
| 9 | Central location, obtain in emergency | x | x | o |
| 10 | MSDS in any form, readily accessible | x | o | o |

Table 10. Frequency of Mention of Expert 29 CFR 1910.1200 (g) Concepts by 3 Specialists

Table 10 shows the frequency with which each concept pertaining to MSDS and related to employee training, was mentioned by the specialists. These concepts are signified with an "x" if correct, otherwise, an "o" indicates a conceptual gap which may be attributed to ignorance, misconception or confusion about the regulation (same measuring system will be used for Tables 11, 12, and 13). Consistent with the greater completeness at the more general level, specialists mentioned individual general concepts (secondary and tertiary) more frequently. Almost every general concept was mentioned by at least one of the three specialists, whereas many specific concepts (quaternary and pentenary) were never mentioned at all.

| 29 CFR | | Company | | |
|---|---|---|---|---|
| 1910.1200 | Regulatory Abstract/section | A | B | C |
| f) | **Labeling and Marking System** | x | x | x |
| 1 | Each container should have the following: | x | x | x |
| i | Identity | x | x | x |
| ii | Hazard warnings | x | x | x |
| iii | Name and address of chemical mfg. | o | o | o |
| 5 | Each container labeled, tagged, or marked | x | x | x |
| i | Identity of hazardous chemical | x | x | x |
| ii | Appropriate hazard warnings | x | x | x |
| iii | Name and address of chemical mfg. | o | o | o |
| 6 | Signs, placards, etc. for stationary process containers | x | o | o |
| 7 | Not required to label portable containers | x | o | o |
| 8 | Do not remove or deface label unless immediately marked | o | x | o |
| 9 | All labels in English | o | o | o |
| 10 | No new labels if old one conveys appropriate information | o | x | o |

Table 11. Frequency of Mention of Expert 29 CFR 1910.1200 (f) Concepts by 3 Specialists

Although most detailed concepts in the MSDS quadrant were not mentioned, two of the three specialists did have a firm understanding of three sections: employee training, labeling and marking system, and written plan. Specifically, specialists covered the majority of the concepts in those three quadrants aforementioned (Tables 11, 12, and 13). One specialist, surprisingly, didn't know that employees need to be informed about the written plan. This person believed that the written plan was for OSHA personnel only.

| 1910.1200 | Regulatory Abstract/section | A | B | C |
|---|---|---|---|---|
| e) | **Written Plan** | x | x | o |
| 1 | Written HazCom program (f), (g), and (h) | x | x | o |
| i | A list of hazardous chemicals | x | x | o |
| ii | Hazards of nonroutine tasks, *unlabeled pipes* | xo | xo | oo |
| 2 | Multi-employer workplaces | x | x | o |
| i | Access to MSDS | x | x | o |
| ii | Precautions to protect employees | x | x | o |
| iii | Labeling system used | x | x | o |
| 3 | Multi-employer workplaces, one geographical location | x | x | o |

Table 12. Frequency of Mention of Expert 29 CFR 1910.1200 (e) Concepts by 3 Specialists

Every specialist failed to mention "methods and observations used to detect the presence or release of a hazard chemical." Moreover, specialists failed to mention some of the basic concepts that should be presented in training: "labels should be in English", "label must have the name and address of the chemical manufacturer", and "labels should never be removed unless either immediately marked". Only one specialist mentioned that MSDS can be in any form and should be readily accessible.

| 29 CFR 1910.1200 | Regulatory Abstract/section | Company A | B | C |
|---|---|---|---|---|
| h) | **Employee Training** | x | x | x |
| 1 | Initial assignment, new physical/health hazards, *new work area* | xxo | xxo | xxx |
| 2 | Information | x | x | x |
| I | The req. of this section | x | x | o |
| ii | Any operation where haz. chem. are present | x | x | x |
| iii | Location of written plan, list of haz. chem., MSDS | xxx | xxx | oox |
| 3 | Training | x | x | x |
| I | Methods and obs. used to detect presence or release | o | o | x |
| ii | Physical and health hazards | xx | xx | xx |
| iii | PPE, emergency procedures | xx | xx | xx |
| iv | Labeling system, use haz. information, details of HazCom | xxx | xxx | xxo |

Table 13. Frequency of Mention of Expert 29 CFR 1910.1200 (h) Concepts by 3 Specialists

Overall, specialists showed much less awareness of the MSDS concepts compared to the other three major concepts. When the tables are coupled with the regulatory expert diagram, they show that the specialists covered a large majority of the training expert concepts mandated by OSHA's ERTK standard. Specialists provided additional factors or concepts that may confound and complicate the educational process for employees; like TLVs, PELs, and reportable quantities.

| 29 CFR 1910.1200 | Regulation or misnomer | Company A | B | C |
|---|---|---|---|---|
| | *Peripheral beliefs* | | | |
| * | Reportable quantity (RQ) | x | | |
| (g) 7i | MSDS updated with initial shipment | | x | |
| * | Emergency evacuation procedures (including tornados) | | | x |
| * | Have chemical at training | | | x |
| * | Contractors (multi-employer) have access to safety manual | | | x |
| | *Indiscriminate beliefs* | | | |
| * | Annual training | x | | x |
| * | Deficiency in practice | x | | |
| * | Request training | x | | |
| * | HMIS warning system | x | x | x |
| * | LABEL - Date chemical prepared | x | | |
| * | Chemical is a carcinogen | x | | x |
| * | MSDS - terminology and understanding | | x | |
| * | MSDS - Emergency numbers | | x | |
| (g) 2iv | MSDS - PEL and TLV | | x | |
| (g)2xi | MSDS - Date of preparation | | x | |
| * | PPE - limitations | | x | |

Table 14. Frequency of Mention of Non-Expert 29 CFR 1910.1200 Concepts by 3 Specialists

Table 14 shows the frequency with which different kinds of specialists nonexpert concepts were mentioned. For instance, all three specialists reported the HMIS warning system used to train employees about chemical hazards. This system, similar to the NFPA warning system in Chapter II, is not conceptually wrong, but an added tool to provide employees with a deeper breadth of knowledge about those hazards in the workplace. There is, obviously, some degree of difference in the views specialist hold in regard to training employees. Again, their views are not conceptually wrong but rather an emphasis on either the "employee" or management's commitment to ERTK.

## Data Analysis of the ERTK Questionnaire

Responses were received and analyzed for each company. Table 15 identifies the number of questionnaires eliminated for use in the analysis because they were incomplete (e.g. missing a large proportionate number of responses or failed to complete a majority of the questionnaire).

| Company | No. Returned | No. Eliminated |
|---|---|---|
| A | 92 | 2 |
| B | 37 | 0 |
| C | 58 | 1 |

Table 15. Eliminated Questionnaires

The ERTK questionnaire is divided into five sections: employee profile, general knowledge of Hazard Communication Standards, in-house safety evaluation, personal protective equipment, and a multiple-choice examination over some general training concepts of the ERTK standard. Each section was analyzed using percentages or averages and standard deviations to determine trends of employee knowledge or perceptions as it pertains to the HazCom standard for each company.

The following sections divide each portion of the questionnaire into its respective divisions. The specific results of the findings may be seen in the various tables in the following subsections. Appendix I, J, and K provide a more detailed analysis for each company's employees responses. Only those questions relevant to providing immediate feedback to their HazCom program, as it pertains to employee training, will be examined.

PROFILE OF THE EMPLOYEE

Section I of the questionnaire presents an analysis of the employee, identified by their respective job title, and their employment history with their current employer. The questionnaire contained one question that asked them to identify their job title. A space was allowed to specify any job title or description of responsibilities. Cumulative aggregate data will be provided to each company should they wish to analyze the data more specifically by various job title or veteran versus novice employees.

| | Company | | | | | |
|---|---|---|---|---|---|---|
| | A | | B | | C | |
| | Avg | Std. Dev. | Avg | Std. Dev. | Avg | Std. Dev. |
| Duration (yrs) | 7.23 | 3.01 | 14.09 | 8.57 | 6.42 | 5.95 |

Table 16. Section I: Employee Profile

Respondents were also asked to indicate length of employment with their employer. Table 16 identifies the average service time of the employees involved in the study. The average length of employment with company A, B, and C is 7.23, 14.09, and 6.42 years, respectively.

GENERAL KNOWLEDGE OF HAZCOM

Section II of the questionnaire presents an analysis of each company's employees general knowledge and application of the standard including a survey of those hazards in their workplace. The questionnaire contained at least one question for training, chemicals list, MSDS, written plan, level of understanding in reading and comprehending an MSDS or chemical label, and the hazards associated with their job. Briefly, each question can be summarized for each company as follows:

1. Were they trained in HazCom at the start of employment?
2. How often are they retrained?
   (0 - never, 1 - annually, 2 - monthly, 4 - daily)
3. Do they have a chemicals list for their work area?
4. Do they know where the MSDS are located?
5. Were they trained in reading and comprehending an MSDS?
6. How often do they consult an MSDS?
   (0 - never, 1 - annually, 2 - monthly, 4 - daily)
7. Were they trained in reading a chemical label and their hazard warnings?
8. How well were they trained? (0 - poorly, 5 - very good)

**9.** Do they know where the written plan is located?

**10.** How hazardous are the chemicals in their area?
(0 - poorly, 5 - very good)

**11.** How they rate the specific hazards in their area?
(0 - poorly, 5 - very good)

| | Company | | | | | |
|---|---|---|---|---|---|---|
| | A | | B | | C | |
| Question # | Avg or % | Std. Dev. | Avg or % | Std. Dev. | Avg or % | Std. Dev. |
| **1** | **0.90** | **-** | **0.68** | **-** | **0.72** | **-** |
| 2 | 1.01 | 0.18 | 0.95 | 0.23 | 1.30 | 0.76 |
| **3** | **0.86** | **-** | **0.76** | **-** | **0.70** | **-** |
| **4** | **0.99** | **-** | **1.00** | **-** | **0.89** | **-** |
| 5 | 0.92 | - | 0.92 | - | 0.79 | - |
| 6 | 0.74 | 0.88 | 1.38 | 0.95 | 0.58 | 0.86 |
| **7** | **1.00** | **-** | **0.97** | **-** | **0.81** | **-** |
| 8 | 3.34 | 1.15 | 3.81 | 1.13 | 3.07 | 1.46 |
| **9** | **0.25** | **-** | **0.68** | **-** | **0.56** | **-** |
| 10 | 2.33 | 1.45 | 3.06 | 1.49 | 3.16 | 1.57 |
| 11 | 2.40 | 1.30 | 2.86 | 1.36 | 3.22 | 1.36 |

Table 17. Section II: General HazCom Knowledge

Table 17 represents the analysis of each question in section II. Questions 1, 3, 4, 7 and 9, signified in bold numbers, are the most significant and relevant questions to the ERTK standard. The other questions were designed with the company's intent to determine what they have learned, gained, and implemented in their job relative to the standard.

The standard mandates that everyone must be trained if hazardous chemicals are present (Question 1). Data revealed that 90, 68 and 72% of the respondents, for company A, B, and C, respectively, were trained in ERTK at their initial assignment.

Question 3 asked the respondents if they knew where the chemical list was located in their area. Only 86, 76 and 70% of the respondents knew of its location for company A, B, and C, respectively.

Respondents were asked if they knew the location of the MSDS for their work area (Question 4). An overwhelming majority of respondents knew of its location as revealed by the 99, 100, and 89% for company A, B, and C, respectively. Question 7 asked the respondents if they were trained in reading a chemical label and appropriate hazard warnings. Again, a surprising 100, 97, and 81% of the respondents were trained in this very crucial component of the standard.

The last important question pertaining to ERTK, Question 9, asked the respondents if they knew the location of the written hazard communication plan. Company A, B, and C's respondents did poorly in this question as evident by a 25, 68 and 56%, respectively. One could assume that the employees, based upon the MM study, weren't provided the required information as to the whereabouts of the written plan.

IN-HOUSE SAFETY EVALUATION

Section III of the questionnaire asked respondents to evaluate current safety work practices implemented by their company. Each question can be summarized as follows:

1. Have they ever notified their employer of unsafe work practices?
2. Have they ever notified their employer of any exposures to chemicals?
3. How would they rate the company's overall concern for safety?
   (0- poor, 5 - very good)
4. How would they rate the employer's response to any problems regarding safety?

| | Company | | | | | |
|---|---|---|---|---|---|---|
| | A | | B | | C | |
| Question # | Avg or % | Std. Dev. | Avg or % | Std. Dev. | Avg or % | Std. Dev. |
| 1 | 0.72 | - | 0.68 | - | 0.77 | - |
| 2 | 0.26 | - | 0.46 | - | 0.57 | - |
| 3 | 4.01 | 1.01 | 4.11 | 1.22 | 3.47 | 1.24 |
| 4 | 3.94 | 1.02 | 4.14 | 1.06 | 3.39 | 1.27 |

Table 18. Section III: In-House Safety Evaluation

Table 18 contains an analysis of the responses for each company. Overall, company A, B, and C have 72, 68, and 77 percent of their respondents indicating that they have notified their employer of unsafe work practices; 26, 46, and 57% have notified their employer of chemical exposures. The employees overall rating of safety concern is 4.01, 4.11, and 3.47 out of 5 with a company's safety response rate evaluated at 3.94, 4.14, and 3.39 out of 5, respectively for company A, B, and C.

PERSONAL PROTECTIVE EQUIPMENT

Section IV asked respondents to indicate if they supply their own PPE, any prior training to wear it effectively, any knowledgeable limitations their PPE may have, and a rating of the "level" of protection their PPE provides in their chemical environment. The questions can be summarized as follows:

1. How often do they wear their assigned PPE? (0 - never, 5 - always)
2. Do they supply their own PPE?
3. Were they trained to use PPE effectively?
4. Do they know their limitations, useful life, disposal, and proper care?
5. How do they rate the level of protection their PPE provides?
   (0 - poor; 5 - very good)

| | Company | | | | | |
|---|---|---|---|---|---|---|
| | A | | B | | C | |
| Question # | Avg or % | Std. Dev. | Avg or % | Std. Dev. | Avg or % | Std. Dev. |
| 1 | 4.12 | 1.14 | 4.43 | 1.12 | 3.8 | 1.43 |
| 2 | 0.08 | - | 0.14 | - | 0.07 | - |
| 3 | 0.95 | - | 0.97 | - | 0.93 | - |
| 4 | 0.82 | - | 0.92 | - | 0.88 | - |
| 5 | 3.95 | 0.88 | 4.19 | 0.67 | 3.86 | 0.96 |

Table 19. Section IV: Personal Protective Equipment

Table 19 contains an analysis of the PPE study. Each company had a surprising percentage indicating they were trained in wearing PPE correctly as evident by the respondents 95, 97, and 93% for company A, B, and C, respectively. Moreover, the respondents knew the PPE limitations and the level of protection it provides by 82, 92 and 88% for those companies aforementioned.

HAZCOM EXAM

The ERTK exam, a 10 question multiple-choice section, revealed that an average score of 61, 75, and 57% of the respondents knew the required information as it pertains to the standard (Table 20).

| | Company | | | | | |
|---|---|---|---|---|---|---|
| | A | | B | | C | |
| Question # | Avg or % | Std. Dev. | Avg or % | Std. Dev. | Avg or % | Std. Dev. |
| 1 | 0.89 | - | 0.97 | - | 0.82 | - |
| 2 | 0.27 | - | 0.49 | - | 0.46 | - |
| **3** | **0.90** | **-** | **1.00** | **-** | **0.68** | **-** |
| **4** | **0.30** | **-** | **0.57** | **-** | **0.21** | **-** |
| **5** | **0.79** | **-** | **0.81** | **-** | **0.77** | **-** |
| **6** | **0.70** | **-** | **0.95** | **-** | **0.54** | **-** |
| 7 | 0.10 | - | 0.05 | - | 0.07 | - |
| **8** | **0.73** | **-** | **1.00** | **-** | **0.88** | **-** |
| 9 | 0.43 | - | 0.65 | - | 0.42 | - |
| **10** | **0.94** | **-** | **1.00** | **-** | **0.82** | **-** |
| **Score (%)** | **0.61** | **0.17** | **0.75** | **0.11** | **0.57** | **0.16** |

Table 20. Section V: Multiple-choice HazCom Examination

The most significant questions that each company should be concerned with 3, 4, 5, 6, 8, and 10. The information that was gained from this examination is that a majority of the respondents didn't know the following:

- What is a carcinogen? (Question 3)
- What language must an MSDS be written in? (Question 4)
- What is the difference between a physical and health hazard? (Question 5)
- What is the difference between an acute and chronic hazard? (Question 6)
- What items must be on a chemical label? (Question 8)
- When should they be trained in Hazard Communication? (Question 10)

It should be noted that company B did extremely well in almost every category on the exam. It was revealed later that they were trained before responding to the questionnaire; ultimately to boost their "scores". One would assume that they should have done extremely well in every section, given the answers were provided ahead of time. Only one conclusion could be drawn from the poor responses to questions 2, 4, 7, and 9; the specialist didn't know the correct answer. The answers were not provided to either the specialist or respondents until data was collected and studied. As for the speculation of the specialist(s) misunderstanding or ignorance of the questionnaire, especially the HazCom exam, it will hopefully be resolved and revealed through the MM portion of the study.

## Summary

This chapter has presented an analysis of the responses received from the ERTK research questionnaire and the MM study. The responses were tabulated and reported using percentages or averages and standard deviations for each question per company. The MM study showed deviations from the expert model for each specialist. The results were summarized and presented through the discussion, figures, and tables within this chapter. The conclusions and recommendations for both the ERTK MM and ERTK survey are presented in Chapter VI.

# CHAPTER VI

## SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Employees have the *right-to-know* about the hazards in their work place as mandated by OSHA's *Hazard Communication* (HazCom) Standard, 29 CFR 1910.1200 subpart Z. It is this essential requirement that keeps industry trying new ways to inform their employees of their right to protect themselves as well minimizing the company's own liability. Constant and innovative education and training is required to make this standard successful, promoting knowledgeable workers who are concerned about their own safety and health (Asfahl, 1995).

The *Employee Right-to-Know* (ERTK) requires the employer to provide the employees with three tools to help them to learn about the materials they work with on a regular basis. They are:

1. Labeling and other forms of warning
2. MSDSs
3. The written hazard communication program

Ethically, the employer should present information that is both accurate and valuable, and to provide a working environment that is conducive to learning as well as applying the new information.

There is no such thing as a HazCom program that fits every employee in the work place. Each employee needs to know different information at different levels, depending primarily on their job description and chemical interaction their job requires. The employee with greatest chemical interaction needs specific knowledge rather than the employee with limited or no chemical interaction which requires only general awareness. The targeted approach is much more effective when it comes to training than the general approach (Baldwin, 1992), however, every employee must know the generalities of the standard.

The ERTK standard is a training regulation and a guideline to better management. Good communication between the employees and employer make companies stronger and less vulnerable.

The purpose of this study was to assess local specialists' and employee's knowledge of the HazCom standard in a select group of industries in Oklahoma. This was accomplished through a diagnostic tool, a novel regulatory expert mental model, that was constructed based on OSHA's ERTK standard. In addition, a collaborative study of employee understanding using an interpretative analysis of data obtained from questionnaires was used to validate the study. The data returned on the questionnaires were interpreted and analyzed to determine areas of ignorance or confusion of HazCom program. Both studies coupled together should reveal areas of ignorance, misconception, or confusion among the specialists and employees, relative to the standard.

## Results of the Study

The results of this study are summarized in the two sections according to (1) mental modeling study, and (2) the research questionnaire. Moreover, Chapter I raised some important research questions, each addressed below.

1. *Can MM be used as a diagnostic tool to assess the quality of local specialist's knowledge? If so, what are the procedures or steps to develop such a regulatory expert mental model that identifies knowledge structures conveying the appropriate regulatory information?*

   This study proved that MM can be used as a diagnostic tool. However, it was the marriage between Federal regulations and MM that made the most significant and unique contribution to research and industry.

   To carry out a similar MM study, there are three essential steps that must be used. They are:

   A. The expert model, regulatory or otherwise, should not be too complicated because it will be used as a reference guide to uncover the targeted person's views. It should be both accurate and coherent (see Chapter IV and V).
   B. The second procedure is the open-ended interviewing process. It should be conducted with a relaxed individual who is willing to be subjected to inquiry on a given subject. This forum is

designed to tap areas of ignorance and elicit knowledge of expert facts and their beliefs that neither puts new concepts in their minds nor leaves existing ones unstated.

C. The third procedure is to analyze the subjects responses (see Chapter V) by coding responses into a common set of categories.

2. *Does MM offer insight into potential areas of ignorance, confusion or misconceptions concerning the Hazard Communication Standard? Are these misunderstandings being transmitted to employees through ERTK training?*

The ERTK standard, as it pertains to employee training, is somewhat complicated to decipher and understand. This study clearly identified several significant areas of confusion, ignorance, or misconceptions the specialists had relative the standard (see Chapter V). All three specialists had problems associated with what information regarding Hazard Communication training should be relayed to employees. The regulatory expert mental model identified specific concepts of concern each specialist had with all four quadrants in the model.

Even though specialists' misunderstandings were identified, relay of incomplete or inaccurate regulatory information to the employees was not determined.

3. *What practices are used to educate and inform employees of their rights and responsibilities under OSHA's Hazard Communication Standard?*

Although this would be beneficial in elucidating key problems in the dissemination of important ERTK information, this question can not be answered. There are two potential ways to obtain this information, either attend specific HazCom workshops or isolate a random number of employees and interview them about their ERTK training conducted in-house. Questionnaires are ill suited to uncover specific knowledge the employees may have about their company's ERTK training program.

4. *Given that employees are trained in hazard communication, what have they retained through their training?*

The survey identified several key areas that employees retained through ERTK training. In this study, employees appear to have a working

knowledge of the labeling and marking system and the location of the MSDS for their workplace. In addition, employees understand that Hazard Communication is their "right-to-know" as mandated by the standard.

5. *If MM can be used as a diagnostic tool, identify additional applications of regulatory MM that can be used to assess specialist's knowledge?*

   There are many other training Federal regulations that should be studied using a similar and novel mental modeling approach. Other areas of concern are: Community *Right-to-Know* programs, personal protective equipment training, lockout/tagout, confined space entry, incident commander training, 24 Hour HazMat Technician training, and OSHA's 8, 24, and 40 Hour HAZWOPER training. Areas that are not related to federal regulations that could also be explored include first-aid, CPR, hand-gun, piloting, vehicular training (e.g., motorcycle, boating, automobile, etc.), various teaching certifications, SCUBA diving, and paramedic training.

## Mental Modeling Study

This portion of the study offered a novel method for studying specialist's knowledge, as a precursor to developing training tools to aid in the elimination of deficiencies, misconceptions, or ignorance with complicated issues such as Federal regulations. The method's usefulness depends on completing several procedures, each with its own criteria for success. The first such procedure is producing an accurate, and coherent influence diagram (Chapter IV, Figure 8). The diagram should not be too complicated because it will be used as a reference guide to uncover the targeted person's views. The expert mental model in this study, based on 29 CFR 1910.1200, offered comprehensive insight into a complicated training and compliance regulation, and it provided a measure of specialists knowledge.

The second and most critical procedure, the open-ended interviewing process, should be conducted with a relaxed specialist (person) who is willing to be subjected to a battery of questions on a given subject. This forum is designed to tap areas of ignorance and elicit knowledge of expert facts and specialist's beliefs that neither puts new concepts in their minds nor leaves existing ones unstated.

The third procedure is to analyze the specialist's responses (Chapter V) by coding responses into a common set of categories. Here, the categories were provided by the influence diagram (i.e., MSDS, labeling and marking system, written plan, employee training) and supplemented by specialists non-expert concepts. Despite the large number of non-expert concepts (i.e. peripheral, indiscriminate), coding proved fairly reliable and accurate.

This coding scheme produced statistical summaries not only for the frequency of specific beliefs, but also for several aggregate properties of responses, namely their completeness, accuracy, and specificity. These statistics showed that the HazCom specialists knew a majority of the facts in the influence diagram, with the known facts concentrated at some of the highest levels of generality. These results suggest that specialists, like these, have a firm understanding of the ERTK regulation. Every specialist included additional non-expert concepts to their training regimen to protect employees from the hazards in the workplace.

Open-ended interviewing such as the one used in this study is very labor intensive and limited to small samples. However, with the aid of the expert model, interviewing was focused and the analysis was greatly simplified. Consequently, this new method of mental modeling appears to be the only diagnostic tool to discover pertinent misconceptions, ignorance, or confusion about an "expert" concept and provides a useful model to elicit manufactures views on compliance with this standard.

## Research Questionnaire

The ERTK questionnaire provided each company with a measure of training effectiveness implemented in their company. Respondents provided valuable information to both the researcher and specialists by answering a questionnaire. The questionnaire was structured into five subject areas and special consideration was given to the format of the instrument to increase the response rate.

The questionnaire revealed, by a case specific analysis, that many employees have an "average" understanding of the HazCom standard. The most important measure was the 10-question multiple-choice examination. An average score or 61, 75 and 57% for company A, B, and C , respectively, shows that employees should be better trained to meet the standard. Almost every respondent knew where the MSDS were located, yet, did not have an elementary understanding of the vocabulary used on those safety sheets.

The most interesting concept however, that the questionnaire revealed was many employees did not know where the written plan and chemicals list are located. Both items are critical components of the HazCom standard.

The response rate in the study may be characteristic of each company's commitment to ERTK. Low response rates may be indicative of employees unwillingness to provide valuable feedback to the company on their knowledge of ERTK. In addition, poor response rates may be characteristic of a company's concern for employee safety. Research into employee and employer commitment should be conducted in the future. If response rates greatly improve, one could suggest that management's commitment has significantly refocused or employees concern for safety has been heightened.

## Conclusions and Recommendations

The following conclusions and recommendations are based on the results of the descriptive analysis of the effectiveness of HazCom programs in industry as reported on the returned questionnaires and mental modeling study.

1. There are several differences of HazCom knowledge between the specialists and the expert, 29 CFR 1910.1200.
2. It may be concluded that specialists might to have review the regulations more carefully to meet the requirements of 29 CFR 1910.1200.
3. Several sections within the regulation may need clarification. Moreover, there is considerable differences of opinion regarding additional MSDS information used in training. Specialists feel that employees should know more information than what is mandated by the regulation.
4. Current programs could be redesigned or altered to provide employees a background commensurate to the environment with which they work.
5. Specialists may need to be retrained to provide employees a background commensurate with the tasks they are asked to perform.

## Recommendations

Based on an analysis of the responses given by the companies surveyed, the researcher believes that certain recommendations can be offered. The following recommendations are made as a result of studying the data collected.

1. It is recommended that when it comes to learning it is easier to piece together several sessions of learning than one 8 hour training session/year.
2. Knowledge is not gained over night. Training should be conducted more often for newer employees than experienced ones.
3. The employer should present information that is both accurate and valuable, and to provide a work environment that is conducive to learning and applying new information.
4. There is no such thing as a one-size-fits-all ERTK training program. The ERTK should be designed so that all information conveyed through training should be aimed at meeting the *need-to-know* of the employee being trained.
5. Employers should use ERTK training not as a safety meeting but as a venue for getting important messages across (e.g., particular safety or health concerns related to a specific hazardous substance used in the work place).
6. In-house studies should be conducted in the future to obtain comparable data indicating whether improvements or setbacks have occurred.
7. Studies similar to this one should be made in the future on larger systems to determine if the number of people trained at one time impacts the education process.

## Future Research

Assessing knowledge of specialists, such as those who train employees on the ERTK standard, can be very rewarding. Improvements can be found in any system which tries to educate people about some knowledge domain. This process of education is more difficult when the government forces industries to abide by standards using audits with steep penalties as a measure of effectiveness. These audits can be very costly for many companies who may pay enormous fines or even potential jail time for non-compliance. For the ERTK standard, training compliance requires an active, on-going involvement of both employer and employee.

There are many other training Federal regulations that should be studied using a similar mental modeling approach. Other areas of concern are: Community *Right-to-Know* programs, personal protective equipment training, lockout/tagout, confined space entry, incident commander training, 24 Hour HazMat Technician training, and OSHA's 8, 24, and 40 Hour HAZWOPER training. Areas that are not related to federal regulations that could also be explored include first-aid, CPR, hand-gun, piloting, vehicular training

(e.g., motorcycle, boating, automobile, etc.), various teaching certifications, SCUBA diving, and paramedic training.

The novel mental modeling diagram used in this study is an ideal tool for educational opportunities. A recommended computer program could be developed, designed to show a hierarchical progression through each quadrant of the mental modeling regulation. At the touch of a button, specialists and employees alike could benefit from training and education. As an educational tool, one can easily reap the benefits of a multi-component system eliminating all nonessential information that could clutter training or one's mental model.

Future modifications of the regulatory model may include weighting various concepts. This study assumed that all concepts were equally weighted. However, Oklahoma companies probably don't need to worry about training employees that "English" as the primary language than limitations of PPE or routes of entry? Weighting concepts may provide an accurate measure of specialist's knowledge of the regulation pertaining to employee training.

The ERTK questionnaire is another measurement that can reveal important information. Data gathered in this study could have been used to group employees by various occupation titles or specific employment history (e.g., under 1 year of employment, 1-4 years, 4-8 years, etc.). The ERTK questionnaire could also be expanded and elaborated, depending on which focused component is isolated, to reveal trends in ignorance, misconception, or confusion. By having the questionnaire validated by an Educational psychologist, questions can be generated that tap specific knowledge that the researcher may not suspect. This method may uncover some very interesting results.

This study revealed that, although specialists agree upon many expert concepts, there is still more to know. Specialist discrepancies concerning the ERTK standard are quite common. There are always constant battles with Federal regulations, like OSHA's HazCom standard, where interpretation is somewhat nebulous. However, there will always be only one interpretation -- the expert.

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# APPENDIX A. 29 CFR 1910.1200

## 1910.1200 Hazard communication.

(a) Purpose.

(1) The purpose of this section is to ensure that the hazards of all chemicals produced or imported are evaluated, and that information concerning their hazards is transmitted to employers and employees. This transmittal of information is to be accomplished by means of comprehensive hazard communication programs, which are to include container labeling and other forms of warning, material safety data sheets and employee training.

(2) This occupational safety and health standard is intended to address comprehensively the issue of evaluating the potential hazards of chemicals, and communicating information concerning hazards and appropriate protective measures to employees, and to preempt any legal requirements of a state, or political subdivision of a state, pertaining to this subject. Evaluating the potential hazards of chemicals, and communicating information concerning hazards and appropriate protective measures to employees, may include, for example, but is not limited to, provisions for: developing and maintaining a written hazard communication program for the workplace, including lists of hazardous chemicals present; labeling of containers of chemicals in the workplace, as well as of containers of chemicals being shipped to other workplaces; preparation and distribution of material safety data sheets to employees and downstream employers; and development and implementation of employee training programs regarding hazards of chemicals and protective measures. Under section 18 of the Act, no state or political subdivision of a state may adopt or enforce, through any court or agency, any requirement relating to the issue addressed by this Federal standard, except pursuant to a Federally-approved state plan.

(b) Scope and application.

(1) This section requires chemical manufacturers or importers to assess the hazards of chemicals which they produce or import, and all employers to provide information to their employees about the hazardous chemicals to which they are exposed, by means of a hazard communication program, labels and other forms of warning, material safety data sheets, and information and training. In addition, this section requires distributors to transmit the required information to employers. (Employers who do not produce or import chemicals need only focus on those parts of this rule that deal with establishing a workplace program and communicating information to their workers. Appendix E of this section is a general guide for such employers to help them determine their compliance obligations under the rule.)

(2) This section applies to any chemical which is known to be present in the workplace in such a manner that employees may be exposed under normal conditions of use or in a foreseeable emergency.

(3) This section applies to laboratories only as follows:

(i) Employers shall ensure that labels on incoming containers of hazardous chemicals are not removed or defaced;

(ii) Employers shall maintain any material safety data sheets that are received with incoming shipments of hazardous chemicals, and ensure that they are readily accessible during each workshift to laboratory employees when they are in their work areas;

(iii) Employers shall ensure that laboratory employees are provided information and training in accordance with paragraph (h) of this section, except for the location and availability of the written hazard communication program under paragraph (h)(2)(iii) of this section; and,

(iv) Laboratory employers that ship hazardous chemicals are considered to be either a chemical manufacturer or a distributor under this rule, and thus must ensure that any containers of hazardous chemicals leaving the laboratory are labeled in accordance with paragraph (f)(1) of this section, and that a material safety data sheet is provided to distributors and other employers in accordance with paragraphs (g)(6) and (g)(7) of this section.

(4) In work operations where employees only handle chemicals in sealed containers which are not opened under normal conditions of use (such as are found in marine cargo handling, warehousing, or retail sales), this section applies to these operations only as follows:

(i) Employers shall ensure that labels on incoming containers of hazardous chemicals are not removed or defaced;

(ii) Employers shall maintain copies of any material safety data sheets that are received with incoming shipments of the sealed containers of hazardous chemicals, shall obtain a material safety data sheet as soon as possible for sealed containers of hazardous chemicals received without a material safety data sheet if an

employee requests the material safety data sheet, and shall ensure that the material safety data sheets are readily accessible during each work shift to employees when they are in their work area(s); and,

(iii) Employers shall ensure that employees are provided with information and training in accordance with paragraph (h) of this section (except for the location and availability of the written hazard communication program under paragraph (h)(2)(iii) of this section), to the extent necessary to protect them in the event of a spill or leak of a hazardous chemical from a sealed container.

(5) This section does not require labeling of the following chemicals:

(i) Any pesticide as such term is defined in the Federal Insecticide, Fungicide, and Rodenticide Act (7 U.S.C. 136 et seq.), when subject to the labeling requirements of that Act and labeling regulations issued under that Act by the Environmental Protection Agency;

(ii) Any chemical substance or mixture as such terms are defined in the Toxic Substances Control Act (15 U.S.C. 2601 et seq.), when subject to the labeling requirements of that Act and labeling regulations issued under that Act by the Environmental Protection Agency;

(iii) Any food, food additive, color additive, drug, cosmetic, or medical or veterinary device or product, including materials intended for use as ingredients in such products (e.g. flavors and fragrances), as such terms are defined in the Federal Food, Drug, and Cosmetic Act (21 U.S.C. 301 et seq.) or the Virus-Serum-Toxin Act of 1913 (21 U.S.C. 151 et seq.), and regulations issued under those Acts, when they are subject to the labeling requirements under those Acts by either the Food and Drug Administration or the Department of Agriculture;

(iv) Any distilled spirits (beverage alcohols), wine, or malt beverage intended for nonindustrial use, as such terms are defined in the Federal Alcohol Administration Act (27 U.S.C. 201 et seq.) and regulations issued under that Act, when subject to the labeling requirements of that Act and labeling regulations issued under that Act by the Bureau of Alcohol, Tobacco, and Firearms;

(v) Any consumer product or hazardous substance as those terms are defined in the Consumer Product Safety Act (15 U.S.C. 2051 et seq.) and Federal Hazardous Substances Act (15 U.S.C. 1261 et seq.) respectively, when subject to a consumer product safety standard or labeling requirement of those Acts, or regulations issued under those Acts by the Consumer Product Safety Commission; and,

(vi) Agricultural or vegetable seed treated with pesticides and labeled in accordance with the Federal Seed Act (7 U.S.C. 1551 et seq.) and the labeling regulations issued under that Act by the Department of Agriculture.

(6) This section does not apply to:

(i) Any hazardous waste as such term is defined by the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976, as amended (42 U.S.C. 6901 et seq.), when subject to regulations issued under that Act by the Environmental Protection Agency;

(ii) Any hazardous substance as such term is defined by the Comprehensive Environmental Response, Compensation and Liability ACT (CERCLA) (42 U.S.C. 9601 et seq.) when the hazardous substance is the focus of remedial or removal action being conducted under CERCLA in accordance with Environmental Protection Agency regulations.

(iii) Tobacco or tobacco products;

(iv) Wood or wood products, including lumber which will not be processed, where the chemical manufacturer or importer can establish that the only hazard they pose to employees is the potential for flammability or combustibility (wood or wood products which have been treated with a hazardous chemical covered by this standard, and wood which may be subsequently sawed or cut, generating dust, are not exempted);

(v) Articles (as that term is defined in paragraph (c) of this section);

(vi) Food or alcoholic beverages which are sold, used, or prepared in a retail establishment (such as a grocery store, restaurant, or drinking place), and foods intended for personal consumption by employees while in the workplace;

(vii) Any drug, as that term is defined in the Federal Food, Drug, and Cosmetic Act (21 U.S.C. 301 et seq.), when it is in solid, final form for direct administration to the patient (e.g., tablets or pills); drugs which are packaged by the chemical manufacturer for sale to consumers in a retail establishment (e.g., over-the-counter drugs); and drugs intended for personal consumption by employees while in the workplace (e.g., first aid supplies);

(viii) Cosmetics which are packaged for sale to consumers in a retail establishment, and cosmetics intended for personal consumption by employees while in the workplace;

(ix) Any consumer product or hazardous substance, as those terms are defined in the Consumer Product Safety Act (15 U.S.C. 2051 et seq.) and Federal Hazardous Substances Act (15 U.S.C. 1261 et seq.) respectively, where the employer can show that it is used in the workplace for the purpose intended by the chemical manufacturer or importer of the product, and the use results in a duration and frequency of exposure which is not greater than the range of exposures that could reasonably be experienced by consumers when used for the purpose intended;

(x) Nuisance particulates where the chemical manufacturer or importer can establish that they do not pose any physical or health hazard covered under this section;

(xi) Ionizing and nonionizing radiation; and,

(xii) Biological hazards.

(c) Definitions.

"Article" means a manufactured item other than a fluid or particle:

(i) which is formed to a specific shape or design during manufacture; (ii) which has end use function(s) dependent in whole or in part upon its shape or design during end use; and

(iii) which under normal conditions of use does not release more than very small quantities, e.g., minute or trace amounts of a hazardous chemical (as determined under paragraph (d) of this section), and does not pose a physical hazard or health risk to employees.

"Assistant Secretary" means the Assistant Secretary of Labor for Occupational Safety and Health, U.S. Department of Labor, or designee.

"Chemical" means any element, chemical compound or mixture of elements and/or compounds.

"Chemical manufacturer" means an employer with a workplace where chemical(s) are produced for use or distribution.

"Chemical name" means the scientific designation of a chemical in accordance with the nomenclature system developed by the International Union of Pure and Applied Chemistry (IUPAC) or the Chemical Abstracts Service (CAS) rules of nomenclature, or a name which will clearly identify the chemical for the purpose of conducting a hazard evaluation.

"Combustible liquid" means any liquid having a flashpoint at or above 100°F (37.8°C), but below 200°F (93.3°C), except any mixture having components with flashpoints of 200°F (93.3°C), or higher, the total volume of which make up 99 percent or more of the total volume of the mixture.

"Commercial account" means an arrangement whereby a retail distributor sells hazardous chemicals to an employer, generally in large quantities over time and/or at costs that are below the regular retail price.

"Common name" means any designation or identification such as code name, code number, trade name, brand name or generic name used to identify a chemical other than by its chemical name.

"Compressed gas" means:

(i) A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70°F (21.1°C); or

(ii) A gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130°F (54.4°C) regardless of the pressure at 70°F (21.1°C); or

(iii) A liquid having a vapor pressure exceeding 40 psi at 100°F (37.8°C) as determined by ASTM D-323-72.

"Container" means any bag, barrel, bottle, box, can, cylinder, drum, reaction vessel, storage tank, or the like that contains a hazardous chemical. For purposes of this section, pipes or piping systems, and engines, fuel tanks, or other operating systems in a vehicle, are not considered to be containers.

"Designated representative" means any individual or organization to whom an employee gives written authorization to exercise such employee's rights under this section. A recognized or certified collective bargaining agent shall be treated automatically as a designated representative without regard to written employee authorization.

"Director" means the Director, National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services, or designee.

"Distributor" means a business, other than a chemical manufacturer or importer, which supplies hazardous chemicals to other distributors or to employers.

"Employee" means a worker who may be exposed to hazardous chemicals under normal operating conditions or in foreseeable emergencies. Workers such as office workers or bank tellers who encounter hazardous chemicals only in non-routine, isolated instances are not covered.

"Employer" means a person engaged in a business where chemicals are either used, distributed, or are produced for use or distribution, including a contractor or subcontractor.

"Explosive" means a chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature.

"Exposure or exposed" means that an employee is subjected in the course of employment to a chemical that is a physical or health hazard, and includes potential (e.g. accidental or possible) exposure. "Subjected" in terms of health hazards includes any route of entry (e.g. inhalation, ingestion, skin contact or absorption.)

"Flammable" means a chemical that falls into one of the following categories:

(i) "Aerosol, flammable" means an aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening, or a flashback (a flame extending back to the valve) at any degree of valve opening;

(ii) "Gas, flammable" means:

(A) A gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of thirteen (13) percent by volume or less; or

(B) A gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than twelve (12) percent by volume, regardless of the lower limit;

(iii) "Liquid, flammable" means any liquid having a flashpoint below 100°F (37.8°C), except any mixture having components with flashpoints of 100°F (37.8°C) or higher, the total of which make up 99 percent or more of the total volume of the mixture.

(iv) "Solid, flammable" means a solid, other than a blasting agent or explosive as defined in § 1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard. A chemical shall be considered to be a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a rate greater than one-tenth of an inch per second along its major axis.

"Flashpoint" means the minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite when tested as follows:

(i) Tagliabue Closed Tester (See American National Standard Method of Test for Flash Point by Tag Closed Tester, Z11.24-1979 (ASTM D 56-79)) for liquids with a viscosity of less than 45 Saybolt Universal Seconds (SUS) at 100°F (37.8°C), that do not contain suspended solids and do not have a tendency to form a surface film under test; or

(ii) Pensky-Martens Closed Tester (see American National Standard Method of Test for Flash Point by Pensky-Martens Closed Tester, Z11.7-1979 (ASTM D 93-79)) for liquids with a viscosity equal to or greater than 45 SUS at 100°F (37.8°C), or that contain suspended solids, or that have a tendency to form a surface film under test; or

(iii) Setaflash Closed Tester (see American National Standard Method of Test for Flash Point by Setaflash Closed Tester (ASTM D 3278-78)).

Organic peroxides, which undergo autoaccelerating thermal decomposition, are excluded from any of the flashpoint determination methods specified above.

"Foreseeable emergency" means any potential occurrence such as, but not limited to, equipment failure, rupture of containers, or failure of control equipment which could result in an uncontrolled release of a hazardous chemical into the workplace.

"Hazardous chemical" means any chemical which is a physical hazard or a health hazard.

"Hazard warning" means any words, pictures, symbols, or combination thereof appearing on a label or other appropriate form of warning which convey the specific physical and health hazard(s), including target organ effects, of the chemical(s) in the container(s). (See the definitions for "physical hazard" and "health hazard" to determine the hazards which must be covered.)

"Health hazard" means a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals which are carcinogens,

toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system, and agents which damage the lungs, skin, eyes, or mucous membranes. Appendix A provides further definitions and explanations of the scope of health hazards covered by this section, and Appendix B describes the criteria to be used to determine whether or not a chemical is to be considered hazardous for purposes of this standard.

"Identity" means any chemical or common name which is indicated on the material safety data sheet (MSDS) for the chemical. The identity used shall permit cross-references to be made among the required list of hazardous chemicals, the label and the MSDS.

"Immediate use" means that the hazardous chemical will be under the control of and used only by the person who transfers it from a labeled container and only within the work shift in which it is transferred.

"Importer" means the first business with employees within the Customs Territory of the United States which receives hazardous chemicals produced in other countries for the purpose of supplying them to distributors or employers within the United States.

"Label" means any written, printed, or graphic material displayed on or affixed to containers of hazardous chemicals.

"Material safety data sheet (MSDS)" means written or printed material concerning a hazardous chemical which is prepared in accordance with paragraph (g) of this section.

"Mixture" means any combination of two or more chemicals if the combination is not, in whole or in part, the result of a chemical reaction.

"Organic peroxide" means an organic compound that contains the bivalent -O-O-structure and which may be considered to be a structural derivative of hydrogen peroxide where one or both of the hydrogen atoms has been replaced by an organic radical.

"Oxidizer" means a chemical other than a blasting agent or explosive as defined in § 1910.109(a), that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.

"Physical hazard" means a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water-reactive.

"Produce" means to manufacture, process, formulate, blend, extract, generate, emit, or repackage.

"Pyrophoric" means a chemical that will ignite spontaneously in air at a temperature of 130°F (54.4°C) or below.

"Responsible party" means someone who can provide additional information on the hazardous chemical and appropriate emergency procedures, if necessary.

"Specific chemical identity" means the chemical name, Chemical Abstracts Service (CAS) Registry Number, or any other information that reveals the precise chemical designation of the substance. "Trade secret" means any confidential formula, pattern, process, device, information or compilation of information that is used in an employer's business, and that gives the employer an opportunity to obtain an advantage over competitors who do not know or use it. Appendix D sets out the criteria to be used in evaluating trade secrets.

"Unstable (reactive)" means a chemical which in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or will become self-reactive under conditions of shocks, pressure or temperature.

"Use" means to package, handle, react, emit, extract, generate as a byproduct, or transfer.

"Water-reactive" means a chemical that reacts with water to release a gas that is either flammable or presents a health hazard.

"Work area" means a room or defined space in a workplace where hazardous chemicals are produced or used, and where employees are present.

"Workplace" means an establishment, job site, or project, at one geographical location containing one or more work areas.

(d) Hazard determination.

(1) Chemical manufacturers and importers shall evaluate chemicals produced in their workplaces or imported by them to determine if they are hazardous. Employers are not required to evaluate chemicals unless they choose not to rely on the evaluation performed by the chemical manufacturer or importer for the chemical to satisfy this requirement.

(2) Chemical manufacturers, importers or employers evaluating chemicals shall identify and consider the available scientific evidence concerning such hazards. For health hazards, evidence which is statistically significant and which is based on at least one positive study conducted in accordance with established scientific principles is considered to be sufficient to establish a hazardous effect if the results of the study meet the definitions of health hazards in this section. Appendix A shall be consulted for the scope of health hazards covered, and Appendix B shall be consulted for the criteria to be followed with respect to the completeness of the evaluation, and the data to be reported.

(3) The chemical manufacturer, importer or employer evaluating chemicals shall treat the following sources as establishing that the chemicals listed in them are hazardous:

(i) 29 CFR part 1910, subpart Z, Toxic and Hazardous Substances, Occupational Safety and Health Administration (OSHA); or,

(ii) Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment, American Conference of Governmental Industrial Hygienists (ACGIH) (latest edition). The chemical manufacturer, importer, or employer is still responsible for evaluating the hazards associated with the chemicals in these source lists in accordance with the requirements of this standard.

(4) Chemical manufacturers, importers and employers evaluating chemicals shall treat the following sources as establishing that a chemical is a carcinogen or potential carcinogen for hazard communication purposes:

(i) National Toxicology Program (NTP), Annual Report on Carcinogens (latest edition);

(ii) International Agency for Research on Cancer (IARC) Monographs (latest editions); or

(iii) 29 CFR part 1910, subpart Z, Toxic and Hazardous Substances, Occupational Safety and Health Administration.

Note: The Registry of Toxic Effects of Chemical Substances published by the National Institute for Occupational Safety and Health indicates whether a chemical has been found by NTP or IARC to be a potential carcinogen.

(5) The chemical manufacturer, importer or employer shall determine the hazards of mixtures of chemicals as follows:

(i) If a mixture has been tested as a whole to determine its hazards, the results of such testing shall be used to determine whether the mixture is hazardous;

(ii) If a mixture has not been tested as a whole to determine whether the mixture is a health hazard, the mixture shall be assumed to present the same health hazards as do the components which comprise one percent (by weight or volume) or greater of the mixture, except that the mixture shall be assumed to present a carcinogenic hazard if it contains a component in concentrations of 0.1 percent or greater which is considered to be a carcinogen under paragraph (d)(4) of this section;

(iii) If a mixture has not been tested as a whole to determine whether the mixture is a physical hazard, the chemical manufacturer, importer, or employer may use whatever scientifically valid data is available to evaluate the physical hazard potential of the mixture; and,

(iv) If the chemical manufacturer, importer, or employer has evidence to indicate that a component present in the mixture in concentrations of less than one percent (or in the case of carcinogens, less than 0.1 percent) could be released in concentrations which would exceed an established OSHA permissible exposure limit or ACGIH Threshold Limit Value, or could present a health risk to employees in those concentrations, the mixture shall be assumed to present the same hazard.

(6) Chemical manufacturers, importers, or employers evaluating chemicals shall describe in writing the procedures they use to determine the hazards of the chemical they evaluate. The written procedures are to be made available, upon request, to employees, their designated representatives, the Assistant Secretary and the Director. The written description may be incorporated into the written hazard communication program required under paragraph (e) of this section.

(e) Written hazard communication program.

(1) Employers shall develop, implement, and maintain at each workplace, a written hazard communication program which at least describes how the criteria specified in paragraphs (f), (g), and (h) of this section for labels and other forms of warning, material safety data sheets, and employee information and training will be met, and which also includes the following:

(i) A list of the hazardous chemicals known to be present using an identity that is referenced on the appropriate material safety data sheet (the list may be compiled for the workplace as a whole or for individual work areas); and,

(ii) The methods the employer will use to inform employees of the hazards of non-routine tasks (for example, the cleaning of reactor vessels), and the hazards associated with chemicals contained in unlabeled pipes in their work areas.

(2) Multi-employer workplaces. Employers who produce, use, or store hazardous chemicals at a workplace in such a way that the employees of other employer(s) may be exposed (for example, employees of a construction contractor working on-site) shall additionally ensure that the hazard communication programs developed and implemented under this paragraph (e) include the following:

(i) The methods the employer will use to provide the other employer(s) on-site access to material safety data sheets for each hazardous chemical the other employer(s)' employees may be exposed to while working;

(ii) The methods the employer will use to inform the other employer(s) of any precautionary measures that need to be taken to protect employees during the workplace's normal operating conditions and in foreseeable emergencies; and,

(iii) The methods the employer will use to inform the other employer(s) of the labeling system used in the workplace.

(3) The employer may rely on an existing hazard communication program to comply with these requirements, provided that it meets the criteria established in this paragraph (e).

(4) The employer shall make the written hazard communication program available, upon request, to employees, their designated representatives, the Assistant Secretary and the Director, in accordance with the requirements of 29 CFR 1910.20 (e).

(5) Where employees must travel between workplaces during a workshift, i.e., their work is carried out at more than one geographical location, the written hazard communication program may be kept at the primary workplace facility.

(f) Labels and other forms of warning.

(1) The chemical manufacturer, importer, or distributor shall ensure that each container of hazardous chemicals leaving the workplace is labeled, tagged or marked with the following information:

(i) Identity of the hazardous chemical(s);

(ii) Appropriate hazard warnings; and

(iii) Name and address of the chemical manufacturer, importer, or other responsible party.

(2)(i) For solid metal (such as a steel beam or a metal casting), solid wood, or plastic items that are not exempted as articles due to their downstream use, or shipments of whole grain, the required label may be transmitted to the customer at the time of the initial shipment, and need not be included with subsequent shipments to the same employer unless the information on the label changes;

(ii) The label may be transmitted with the initial shipment itself, or with the material safety data sheet that is to be provided prior to or at the time of the first shipment; and,

(iii) This exception to requiring labels on every container of hazardous chemicals is only for the solid material itself, and does not apply to hazardous chemicals used in conjunction with, or known to be present with, the material and to which employees handling the items in transit may be exposed (for example, cutting fluids or pesticides in grains).

(3) Chemical manufacturers, importers, or distributors shall ensure that each container of hazardous chemicals leaving the workplace is labeled, tagged, or marked in accordance with this section in a manner which does not conflict with the requirements of the Hazardous Materials Transportation Act (49 U.S.C. 1801 et seq.) and regulations issued under that Act by the Department of Transportation.

(4) If the hazardous chemical is regulated by OSHA in a substance-specific health standard, the chemical manufacturer, importer, distributor or employer shall ensure that the labels or other forms of warning used are in accordance with the requirements of that standard.

(5) Except as provided in paragraphs (f)(6) and (f)(7) of this section, the employer shall ensure that each container of hazardous chemicals in the workplace is labeled, tagged or marked with the following information:

(i) Identity of the hazardous chemical(s) contained therein; and,

(ii) Appropriate hazard warnings, or alternatively, words, pictures, symbols, or combination thereof, which provide at least general information regarding the hazards of the chemicals, and which, in conjunction with the other information immediately available to employees under the hazard communication program, will provide employees with the specific information regarding the physical and health hazards of the hazardous chemical.

(6) The employer may use signs, placards, process sheets, batch tickets, operating procedures, or other such written materials in lieu of affixing labels to individual stationary process containers, as long as the alternative method identifies the containers to which it is applicable and conveys the information required by paragraph (f)(5) of this section to be on a label. The written materials shall be readily accessible to the employees in their work area throughout each work shift.

(7) The employer is not required to label portable containers into which hazardous chemicals are transferred from labeled containers, and which are intended only for the immediate use of the employee who performs the transfer. For purposes of this section, drugs which are dispensed by a pharmacy to a health care provider for direct administration to a patient are exempted from labeling.

(8) The employer shall not remove or deface existing labels on incoming containers of hazardous chemicals, unless the container is immediately marked with the required information.

(9) The employer shall ensure that labels or other forms of warning are legible, in English, and prominently displayed on the container, or readily available in the work area throughout each work shift. Employers having employees who speak other languages may add the information in their language to the material presented, as long as the information is presented in English as well.

(10) The chemical manufacturer, importer, distributor or employer need not affix new labels to comply with this section if existing labels already convey the required information.

(11) Chemical manufacturers, importers, distributors, or employers who become newly aware of any significant information regarding the hazards of a chemical shall revise the labels for the chemical within three months of becoming aware of the new information. Labels on containers of hazardous chemicals shipped after that time shall contain the new information. If the chemical is not currently produced or imported, the chemical manufacturer, importers, distributor, or employer shall add the information to the label before the chemical is shipped or introduced into the workplace again.

(g) Material safety data sheets.

(1) Chemical manufacturers and importers shall obtain or develop a material safety data sheet for each hazardous chemical they produce or import. Employers shall have a material safety data sheet in the workplace for each hazardous chemical which they use.

(2) Each material safety data sheet shall be in English (although the employer may maintain copies in other languages as well), and shall contain at least the following information:

(i) The identity used on the label, and, except as provided for in paragraph (i) of this section on trade secrets:

(A) If the hazardous chemical is a single substance, its chemical and common name(s);

(B) If the hazardous chemical is a mixture which has been tested as a whole to determine its hazards, the chemical and common name(s) of the ingredients which contribute to these known hazards, and the common name(s) of the mixture itself; or,

(C) If the hazardous chemical is a mixture which has not been tested as a whole:

(1) The chemical and common name(s) of all ingredients which have been determined to be health hazards, and which comprise 1% or greater of the composition, except that chemicals identified as carcinogens under paragraph (d) of this section shall be listed if the concentrations are 0.1% or greater; and,

(2) The chemical and common name(s) of all ingredients which have been determined to be health hazards, and which comprise less than 1% (0.1% for carcinogens) of the mixture, if there is evidence that the ingredient(s) could be released from the mixture in concentrations which would exceed an established OSHA permissible exposure limit or ACGIH Threshold Limit Value, or could present a health risk to employees; and,

(3) The chemical and common name(s) of all ingredients which have been determined to present a physical hazard when present in the mixture;

(ii) Physical and chemical characteristics of the hazardous chemical (such as vapor pressure, flash point);

(iii) The physical hazards of the hazardous chemical, including the potential for fire, explosion, and reactivity;

(iv) The health hazards of the hazardous chemical, including signs and symptoms of exposure, and any medical conditions which are generally recognized as being aggravated by exposure to the chemical;

(v) The primary route(s) of entry;

(vi) The OSHA permissible exposure limit, ACGIH Threshold Limit Value, and any other exposure limit used or recommended by the chemical manufacturer, importer, or employer preparing the material safety data sheet, where available;

(vii) Whether the hazardous chemical is listed in the National Toxicology Program (NTP) Annual Report on Carcinogens (latest edition) or has been found to be a potential carcinogen in the International Agency for Research on Cancer (IARC) Monographs (latest editions), or by OSHA;

(viii) Any generally applicable precautions for safe handling and use which are known to the chemical manufacturer, importer or employer preparing the material safety data sheet, including appropriate hygienic practices, protective measures during repair and maintenance of contaminated equipment, and procedures for clean-up of spills and leaks;

(ix) Any generally applicable control measures which are known to the chemical manufacturer, importer or employer preparing the material safety data sheet, such as appropriate engineering controls, work practices, or personal protective equipment; (x) Emergency and first aid procedures;

(xi) The date of preparation of the material safety data sheet or the last change to it; and,

(xii) The name, address and telephone number of the chemical manufacturer, importer, employer or other responsible party preparing or distributing the material safety data sheet, who can provide additional information on the hazardous chemical and appropriate emergency procedures, if necessary.

(3) If no relevant information is found for any given category on the material safety data sheet, the chemical manufacturer, importer or employer preparing the material safety data sheet shall mark it to indicate that no applicable information was found.

(4) Where complex mixtures have similar hazards and contents (i.e. the chemical ingredients are essentially the same, but the specific composition varies from mixture to mixture), the chemical manufacturer, importer or employer may prepare one material safety data sheet to apply to all of these similar mixtures.

(5) The chemical manufacturer, importer or employer preparing the material safety data sheet shall ensure that the information recorded accurately reflects the scientific evidence used in making the hazard determination. If the chemical manufacturer, importer or employer preparing the material safety data sheet becomes newly aware of any significant information regarding the hazards of a chemical, or ways to protect against the hazards, this new information shall be added to the material safety data sheet within three months. If the chemical is not currently being produced or imported the chemical manufacturer or importer shall add the information to the material safety data sheet before the chemical is introduced into the workplace again.

(6)(i) Chemical manufacturers or importers shall ensure that distributors and employers are provided an appropriate material safety data sheet with their initial shipment, and with the first shipment after a material safety data sheet is updated;

(ii) The chemical manufacturer or importer shall either provide material safety data sheets with the shipped containers or send them to the distributor or employer prior to or at the time of the shipment;

(iii) If the material safety data sheet is not provided with a shipment that has been labeled as a hazardous chemical, the distributor or employer shall obtain one from the chemical manufacturer or importer as soon as possible; and,

(iv) The chemical manufacturer or importer shall also provide distributors or employers with a material safety data sheet upon request.

(7)(i) Distributors shall ensure that material safety data sheets, and updated information, are provided to other distributors and employers with their initial shipment and with the first shipment after a material safety data sheet is updated; (ii) The distributor shall either provide material safety data sheets with the shipped containers, or send them to the other distributor or employer prior to or at the time of the shipment;

(iii) Retail distributors selling hazardous chemicals to employers having a commercial account shall provide a material safety data sheet to such employers upon request, and shall post a sign or otherwise inform them that a material safety data sheet is available;

(iv) Wholesale distributors selling hazardous chemicals to employers over-the-counter may also provide material safety data sheets for all hazardous chemicals they sell, provide material safety data sheets upon the request of the employer at the time of the over-the-counter purchase, and shall post a sign or otherwise inform such employers that a material safety data sheet is available;

(v) If an employer without a commercial account purchases a hazardous chemical from a retail distributor not required to have material safety data sheets on file (i.e., the retail distributor does not have commercial accounts and does not use the materials), the retail distributor shall provide the employer, upon request, with the name, address, and telephone number of the chemical manufacturer, importer, or distributor from which a material safety data sheet can be obtained;

(vi) Wholesale distributors shall also provide material safety data (b)sheets to employers or other distributors upon request; and,

(vii) Chemical manufacturers, importers, and distributors need not provide material safety data sheets to retail distributors that have informed them that the retail distributor does not sell the product to commercial accounts or open the sealed container to use it in their own workplaces.

(8) The employer shall maintain in the workplace copies of the required material safety data sheets for each hazardous chemical, and shall ensure that they are readily accessible during each work shift to employees when they are in their work area(s). (Electronic access, microfiche, and other alternatives to maintaining paper copies of the material safety data sheets are permitted as long as no barriers to immediate employee access in each workplace are created by such options.)

(9) Where employees must travel between workplaces during a workshift, i.e., their work is carried out at more than one geographical location, the material safety data sheets may be kept at the primary workplace facility. In this situation, the employer shall ensure that employees can immediately obtain the required information in an emergency.

(10) Material safety data sheets may be kept in any form, including operating procedures, and may be designed to cover groups of hazardous chemicals in a work area where it may be more appropriate to address the hazards of a process rather than individual hazardous chemicals. However, the employer shall ensure that in all cases the required information is provided for each hazardous chemical, and is readily accessible during each work shift to employees when they are in their work area(s).

(11) Material safety data sheets shall also be made readily available, upon request, to designated representatives and to the Assistant Secretary, in accordance with the requirements of 29 CFR 1910.20(e). The Director shall also be given access to material safety data sheets in the same manner.

(h) Employee information and training.

(1) Employers shall provide employees with effective information and training on hazardous chemicals in their work area at the time of their initial assignment, and whenever a new physical or health hazard the employees have not previously been trained about is introduced into their work area. Information and training may be designed to cover categories of hazards (e.g., flammability, carcinogenicity) or specific chemicals. Chemical-specific information must always be available through labels and material safety data sheets.

(2) Information. Employees shall be informed of:

(i) The requirements of this section;

(ii) Any operations in their work area where hazardous chemicals are present; and,

(iii) The location and availability of the written hazard communication program, including the required list(s) of hazardous chemicals, and material safety data sheets required by this section.

(3) Training. Employee training shall include at least:

(i) Methods and observations that may be used to detect the presence or release of a hazardous chemical in the work area (such as monitoring conducted by the employer, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released, etc.);

(ii) The physical and health hazards of the chemicals in the work area;

(iii) The measures employees can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect employees from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and personal protective equipment to be used; and,

(iv) The details of the hazard communication program developed by the employer, including an explanation of the labeling system and the material safety data sheet, and how employees can obtain and use the appropriate hazard information.

(i) Trade secrets.

(1) The chemical manufacturer, importer, or employer may withhold the specific chemical identity, including the chemical name and other specific identification of a hazardous chemical, from the material safety data sheet, provided that: (i) The claim that the information withheld is a trade secret can be supported;

(ii) Information contained in the material safety data sheet concerning the properties and effects of the hazardous chemical is disclosed;

(iii) The material safety data sheet indicates that the specific chemical identity is being withheld as a trade secret; and,

(iv) The specific chemical identity is made available to health professionals, employees, and designated representatives in accordance with the applicable provisions of this paragraph.

(2) Where a treating physician or nurse determines that a medical emergency exists and the specific chemical identity of a hazardous chemical is necessary for emergency or first-aid treatment, the chemical manufacturer, importer, or employer shall immediately disclose the specific chemical identity of a trade secret chemical to that treating physician or nurse, regardless of the existence of a written statement of need or a confidentiality agreement. The chemical manufacturer, importer, or employer may require a written statement of need and confidentiality agreement, in accordance with the provisions of paragraphs (i)(3) and (4) of this section, as soon as circumstances permit.

(3) In non-emergency situations, a chemical manufacturer, importer, or employer shall, upon request, disclose a specific chemical identity, otherwise permitted to be withheld under paragraph (i)(1) of this section, to a health professional (i.e. physician, industrial hygienist, toxicologist, epidemiologist, or occupational health nurse) providing medical or other occupational health services to exposed employee(s), and to employees or designated representatives, if:

(i) The request is in writing;

(ii) The request describes with reasonable detail one or more of the following occupational health needs for the information:

(A) To assess the hazards of the chemicals to which employees will be exposed;

(B) To conduct or assess sampling of the workplace atmosphere to determine employee exposure levels;

(C) To conduct pre-assignment or periodic medical surveillance of exposed employees;

(D) To provide medical treatment to exposed employees;

(E) To select or assess appropriate personal protective equipment for exposed employees;

(F) To design or assess engineering controls or other protective measures for exposed employees; and,

(G) To conduct studies to determine the health effects of exposure.

(iii) The request explains in detail why the disclosure of the specific chemical identity is essential and that, in lieu thereof, the disclosure of the following information to the health professional, employee, or designated representative, would not satisfy the purposes described in paragraph (i)(3)(ii) of this section:

(A) The properties and effects of the chemical;

(B) Measures for controlling workers' exposure to the chemical;

(C) Methods of monitoring and analyzing worker exposure to the chemical; and,

(D) Methods of diagnosing and treating harmful exposures to the chemical;

(iv) The request includes a description of the procedures to be used to maintain the confidentiality of the disclosed information; and,

(v) The health professional, and the employer or contractor of the services of the health professional (i.e. downstream employer, labor organization, or individual employee), employee, or designated representative, agree in a written confidentiality agreement that the health professional, employee, or designated representative, will not use the trade secret information for any purpose other than the health need(s) asserted and agree not to release the information under any circumstances other than to OSHA, as provided in paragraph (i)(6) of this section, except as authorized by the terms of the agreement or by the chemical manufacturer, importer, or employer.

(4) The confidentiality agreement authorized by paragraph (i)(3)(iv) of this section:

(i) May restrict the use of the information to the health purposes indicated in the written statement of need;

(ii) May provide for appropriate legal remedies in the event of a breach of the agreement, including stipulation of a reasonable pre-estimate of likely damages; and,

(iii) May not include requirements for the posting of a penalty bond.

(5) Nothing in this standard is meant to preclude the parties from pursuing non-contractual remedies to the extent permitted by law.

(6) If the health professional, employee, or designated representative receiving the trade secret information decides that there is a need to disclose it to OSHA, the chemical manufacturer, importer, or employer who provided the information shall be informed by the health professional, employee, or designated representative prior to, or at the same time as, such disclosure.

(7) If the chemical manufacturer, importer, or employer denies a written request for disclosure of a specific chemical identity, the denial must:

(i) Be provided to the health professional, employee, or designated representative, within thirty days of the request;

(ii) Be in writing;

(iii) Include evidence to support the claim that the specific chemical identity is a trade secret;

(iv) State the specific reasons why the request is being denied; and,

(v) Explain in detail how alternative information may satisfy the specific medical or occupational health need without revealing the specific chemical identity.

(8) The health professional, employee, or designated representative whose request for information is denied under paragraph (i)(3) of this section may refer the request and the written denial of the request to OSHA for consideration.

(9) When a health professional, employee, or designated representative refers the denial to OSHA under paragraph (i)(8) of this section, OSHA shall consider the evidence to determine if:

(i) The chemical manufacturer, importer, or employer has supported the claim that the specific chemical identity is a trade secret;

(ii) The health professional, employee, or designated representative has supported the claim that there is a medical or occupational health need for the information; and,

(iii) The health professional, employee or designated representative has demonstrated adequate means to protect the confidentiality.

(10)(i) If OSHA determines that the specific chemical identity requested under paragraph (i)(3) of this section is not a bona fide trade secret, or that it is a trade secret, but the requesting health professional, employee, or designated representative has a legitimate medical or occupational health need for the information, has executed a written confidentiality agreement, and has shown adequate means to protect the confidentiality of the information, the chemical manufacturer, importer, or employer will be subject to citation by OSHA.

(ii) If a chemical manufacturer, importer, or employer demonstrates to OSHA that the execution of a confidentiality agreement would not provide sufficient protection against the potential harm from the unauthorized disclosure of a trade secret specific chemical identity, the Assistant Secretary may issue such orders or impose such additional limitations or conditions upon the disclosure of the requested chemical information as may be appropriate to assure that the occupational health services are provided without an undue risk of harm to the chemical manufacturer, importer, or employer.

(11) If a citation for a failure to release specific chemical identity information is contested by the chemical manufacturer, importer, or employer, the matter will be adjudicated before the Occupational Safety and Health Review Commission in accordance with the Act's enforcement scheme and the applicable Commission rules of procedure. In accordance with the Commission rules, when a chemical manufacturer, importer, or employer continues to withhold the information during the contest, the Administrative Law Judge may review the citation and supporting documentation in camera or issue appropriate orders to protect the confidentiality of such matters.

(12) Notwithstanding the existence of a trade secret claim, a chemical manufacturer, importer, or employer shall, upon request, disclose to the Assistant Secretary any information which this section requires the chemical manufacturer, importer, or employer to make available. Where there is a trade secret claim, such claim shall be made no later than at the time the information is provided to the Assistant

Secretary so that suitable determinations of trade secret status can be made and the necessary protections can be implemented.

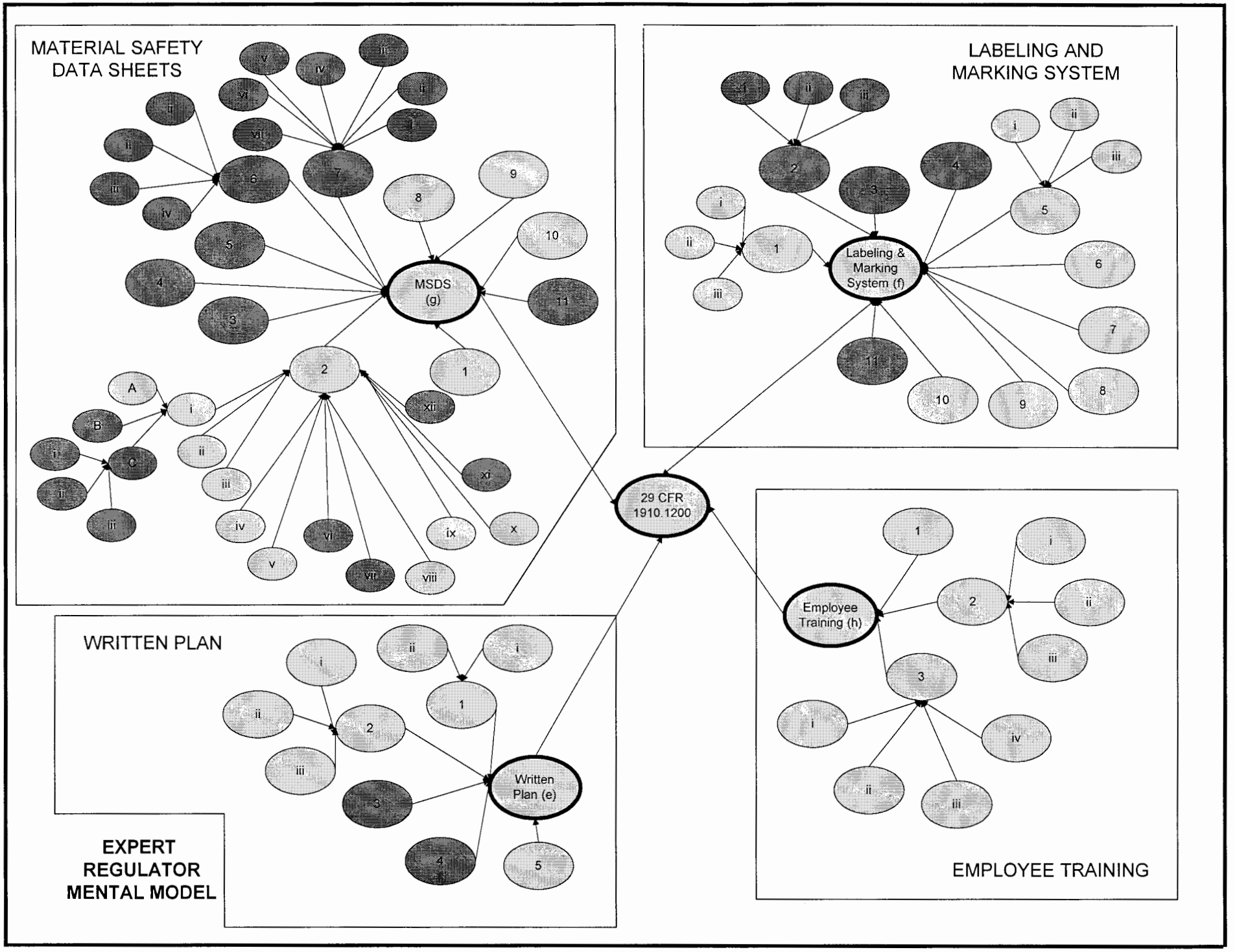
(13) Nothing in this paragraph shall be construed as requiring the disclosure under any circumstances of process or percentage of mixture information which is a trade secret.

(j) Effective dates. Chemical manufacturers, importers, distributors, and employers shall be in compliance with all provisions of this section by March 11, 1994.

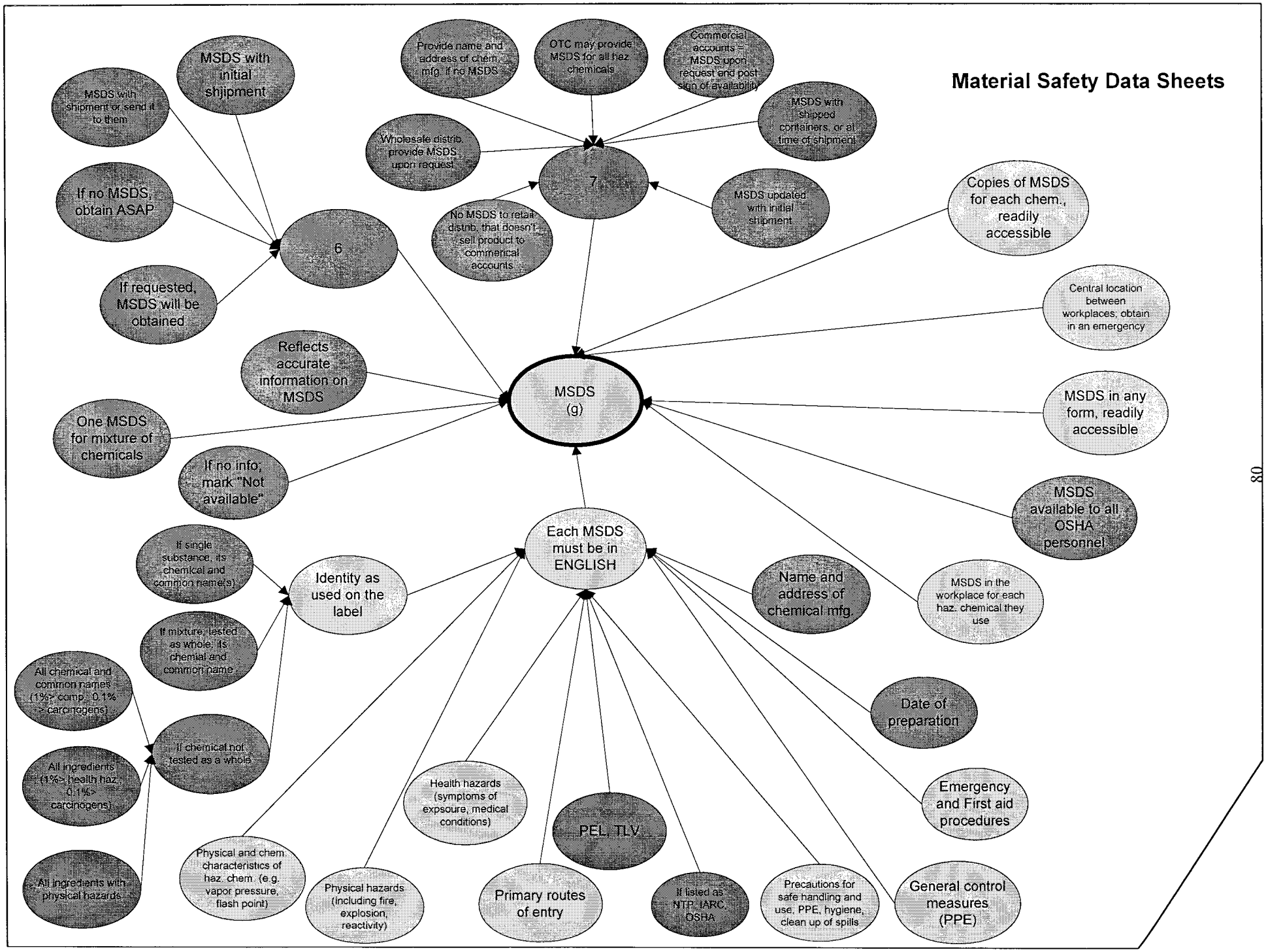
Note: The effective date of the clarification that the exemption of wood and wood products from the Hazard Communication standard in paragraph (b)(6)(iv) only applies to wood and wood products including lumber which will not be processed, where the manufacturer or importer can establish that the only hazard they pose to employees is the potential for flammability or combustibility, and that the exemption does not apply to wood or wood products which have been treated with a hazardous chemical covered by this standard, and wood which may be subsequently sawed or cut generating dust has been stayed from March 11, 1994 to August 11, 1994.

[As amended at 59 FR 6126, Feb. 9, 1994; 59 FR 17478, Apr.13, 1994; 59 FR 65947, Dec. 22, 1994; 61 FR 5507, Feb. 13, 1996]

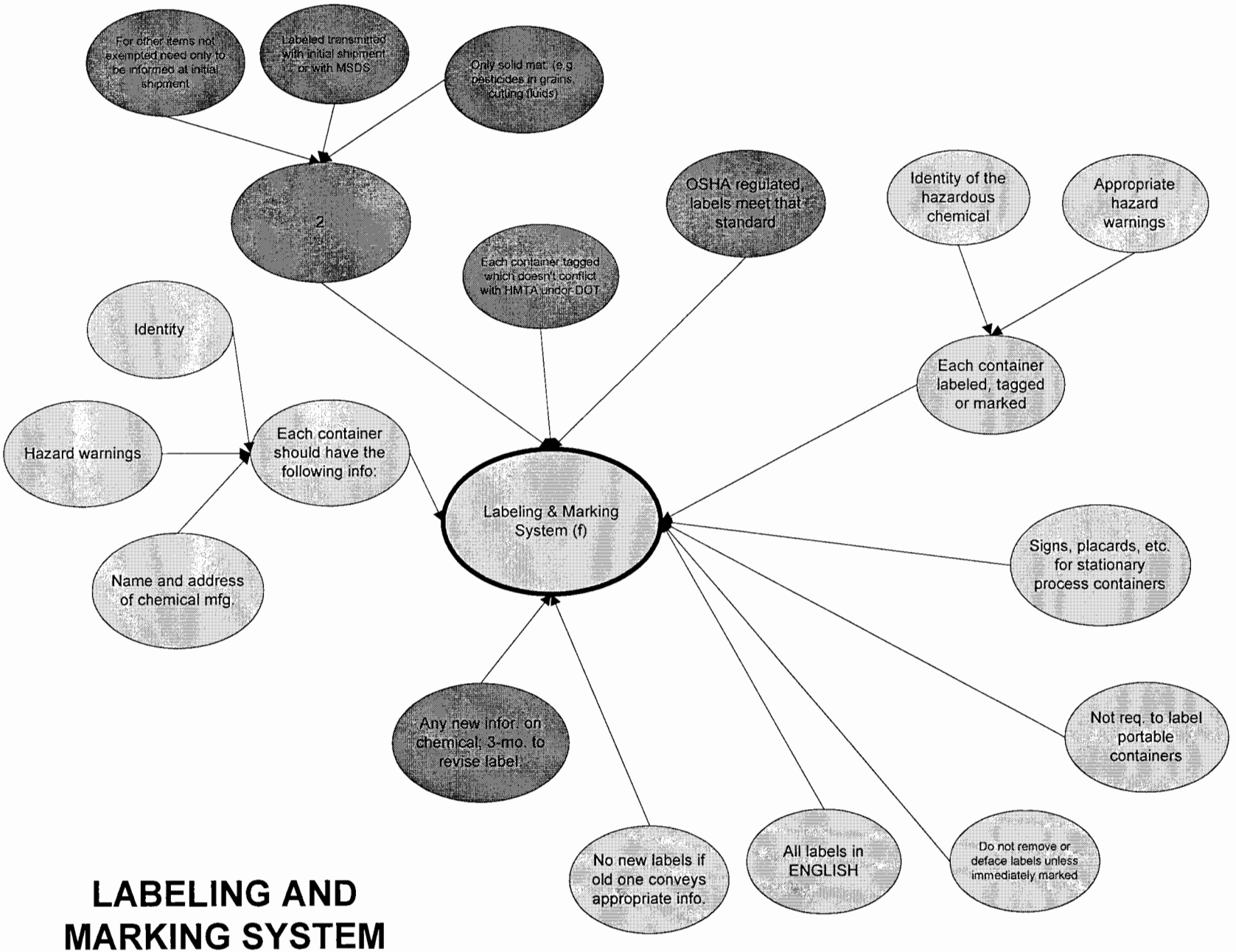
# APPENDIX B. REGULATORY EXPERT MENTAL MODEL OF 29 CFR 1910.1200


MATERIAL SAFETY DATA SHEETS
MSDS (g)
LABELING AND MARKING SYSTEM
Labeling & Marking System (f)
29 CFR 1910.1200
WRITTEN PLAN
Written Plan (e)
EXPERT REGULATOR MENTAL MODEL
Employee Training (h)
EMPLOYEE TRAINING

# APPENDIX C. REGULATORY EXPERT MENTAL MODEL - *MSDS*


Material Safety Data Sheets
MSDS with initial shipment
MSDS with shipment or send it to them
Provide name and address of chem. mfg. if no MSDS
OTC may provide MSDS for all haz chemicals
Commercial accounts – MSDS upon request and post sign of availability
MSDS with shipped containers, or at time of shipment
Wholesale distrib. provide MSDS upon request
7
If no MSDS, obtain ASAP
6
No MSDS to retail distrib. that doesn't sell product to commerical accounts
MSDS updated with initial shipment
Copies of MSDS for each chem., readily accessible
If requested, MSDS will be obtained
Central location between workplaces; obtain in an emergency
Reflects accurate information on MSDS
MSDS (g)
MSDS in any form, readily accessible
One MSDS for mixture of chemicals
If no info, mark "Not available"
MSDS available to all OSHA personnel
Each MSDS must be in ENGLISH
If single substance, its chemical and common name(s)
Identity as used on the label
Name and address of chemical mfg.
MSDS in the workplace for each haz. chemical they use
If mixture, tested as whole, its chemial and common name
All chemical and common names (1%> comp., 0.1% > carcinogens)
If chemical not tested as a whole
Date of preparation
All ingredients (1%> health haz.; 0.1%> carcinogens)
Emergency and First aid procedures
Health hazards (symptoms of expsoure, medical conditions)
PEL, TLV
Physical and chem. characteristics of haz. chem. (e.g. vapor pressure, flash point)
All ingredients with physical hazards
Physical hazards (including fire, explosion, reactivity)
Primary routes of entry
If listed as NTP, IARC, OSHA
Precautions for safe handling and use, PPE, hygiene, clean up of spills
General control measures (PPE)

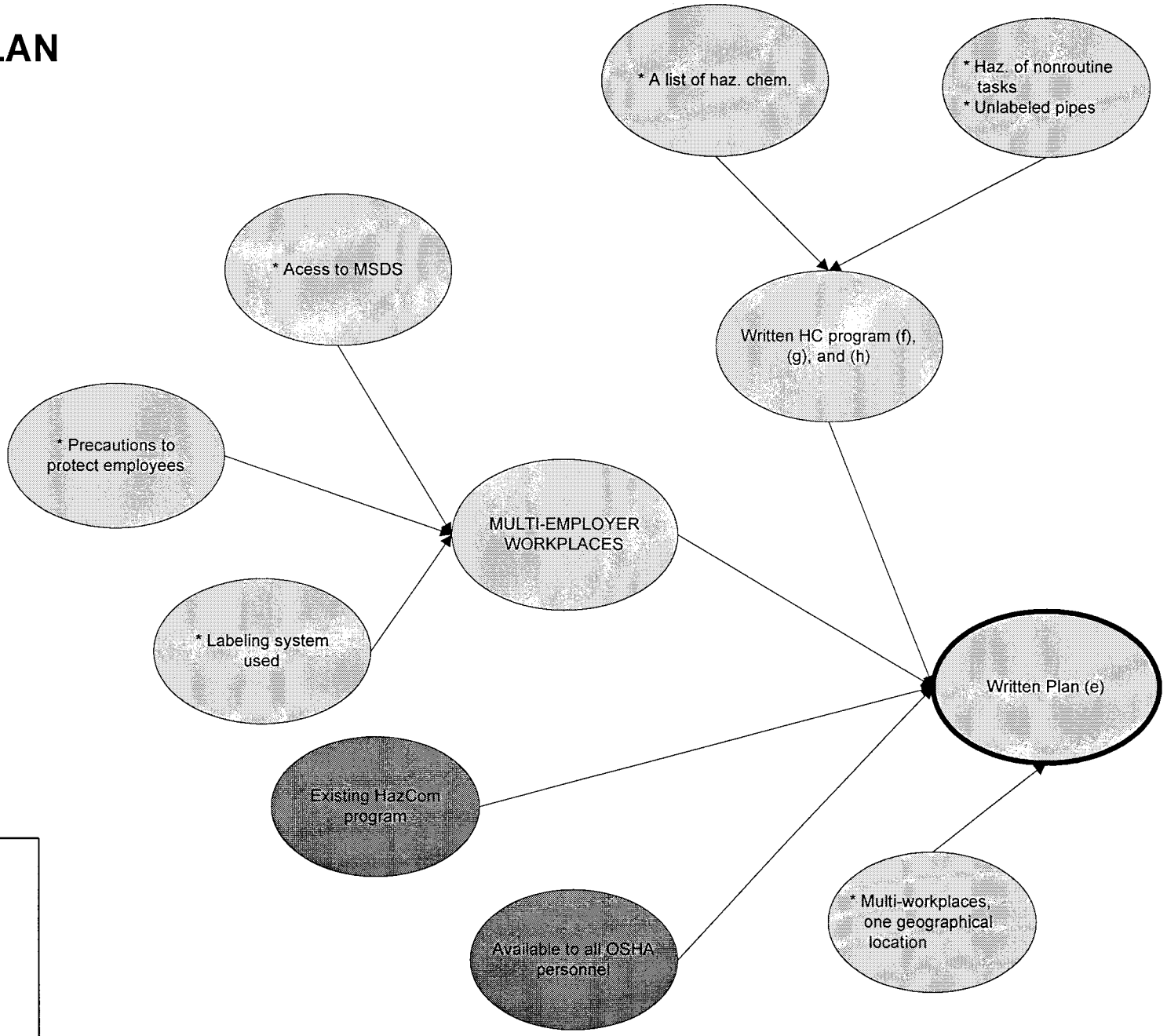
# APPENDIX D. REGULATORY EXPERT MENTAL MODEL - *LABELING AND MARKING SYSTEM*



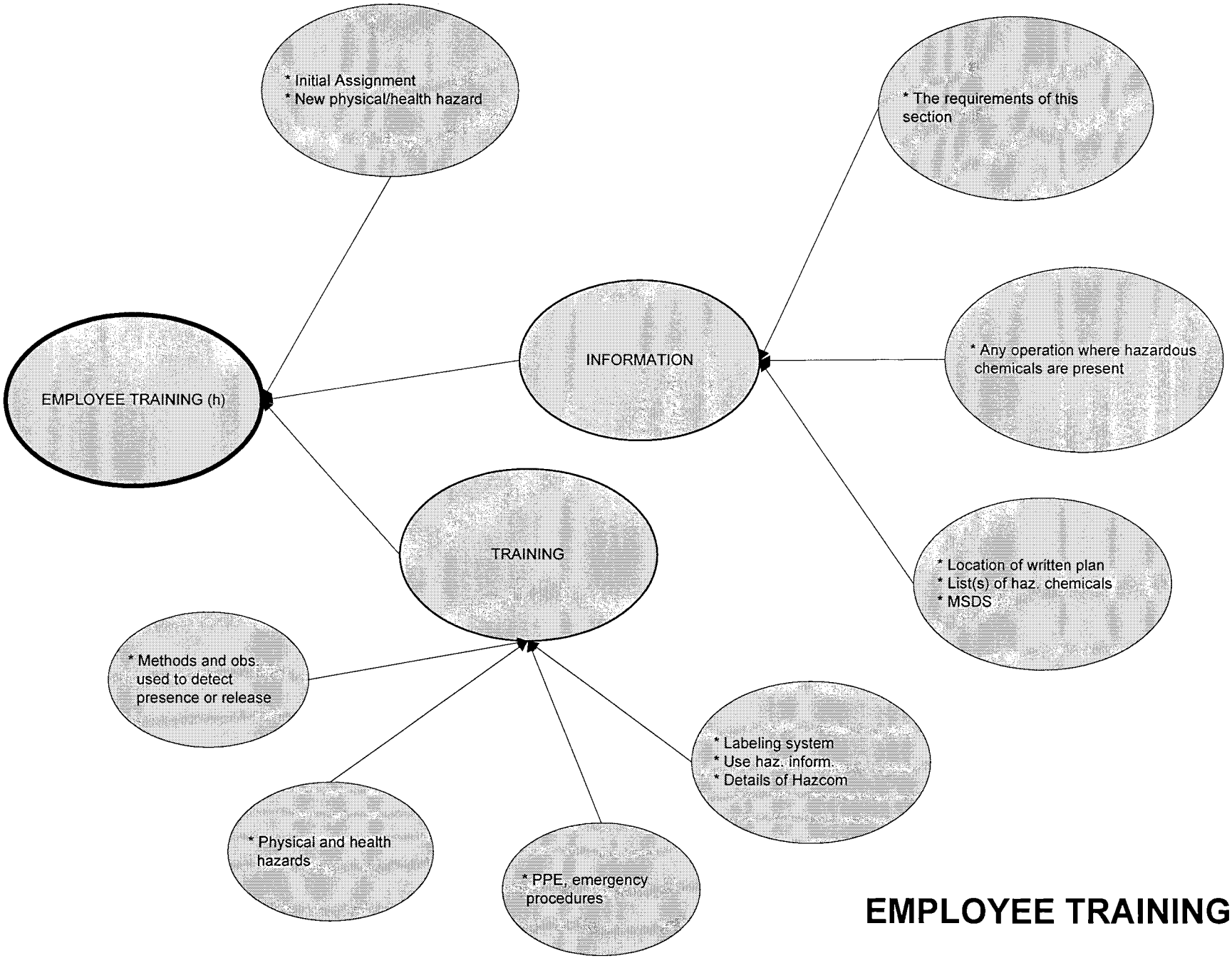

# LABELING AND MARKING SYSTEM

# APPENDIX E. REGULATORY EXPERT MENTAL MODEL - *WRITTEN PLAN*

# WRITTEN PLAN



## APPENDIX F. REGULATORY EXPERT MENTAL MODEL - *EMPLOYEE TRAINING*


* Initial Assignment
* New physical/health hazard
* The requirements of this section
EMPLOYEE TRAINING (h)
INFORMATION
* Any operation where hazardous chemicals are present
TRAINING
* Location of written plan
* List(s) of haz. chemicals
* MSDS
* Methods and obs. used to detect presence or release
* Labeling system
* Use haz. inform.
* Details of Hazcom
* Physical and health hazards
* PPE, emergency procedures
EMPLOYEE TRAINING

# APPENDIX G. ERTK QUESTIONNAIRE

# EMPLOYEE RIGHT TO KNOW SURVEY

The purpose of this survey is to evaluate the Hazard Communication program at your facility. This evaluation is voluntary and confidential and will be used to recognize, improve the existing program.

**Although none of these results will be linked to a specific individual, some information about your position will allow us to better interpret all the responses:**

What is your job title: _____

How long have you been with your present employer? _____

**Please answer the following questions to the best of your ability (please circle/check one):**

1. At the time of your initial assignment (new job, transfer to new work area), were you informed and trained about the hazards associated with your position?
   _____ no _____ yes
2. How often are you retrained by your company's safety/environmental staff?
   _____ never _____ yearly ____ monthly ____ weekly ____ daily
3. Do you have a chemicals list for your work area?
   _____ no _____ yes
4. Do you know where the Material Safety Data Sheets (MSDS) are located in your facility?
   _____ no _____ yes
5. Were you trained in reading and understanding a MSDS?
   _____ no _____ yes
6. How often do you consult the MSDS for chemical information?
   _____ never _____ yearly ____ monthly ____ weekly ____ daily
7. Were you trained in reading a chemical label including hazard warnings?
   _____ no _____ yes
8. How well do you feel trained in reading and understanding a chemical label? (circle one)
   0 1 2 3 4 5
   Poorly Very
9. Do you know where the written employee right-to-know plan is located?
   _____ no _____ yes
10. How hazardous are the chemicals located in your area? (circle one)
    0 1 2 3 4 5
    No Hazards Extremely
11. How would you rate the specific hazards in your work area? (circle one)
    0 1 2 3 4 5
    Poorly Extremely

1. Have you ever notified your employer of unsafe work practices or procedures?
   _____ no _____ yes
2. Have you ever notified your employer of any exposures to chemicals in the workplace?
   _____ no _____ yes
3. How would you rate your companies overall concern for safety? (circle one)
   0 1 2 3 4 5
   Poor Very Good
4. To what degree does your employer respond to any problems regarding safety? (circle one)
   0 1 2 3 4 5
   Never Always

**Please answer all of the following questions about personal protective equipment (PPE) you use at your facility.**

1. How often do you wear PPE when working with any chemical? (circle one)

0 1 2 3 4 5

Never Always

2. Do you supply your own PPE?

_____ no _____ yes

3. Were you trained in how to wear them effectively?

_____ no _____ yes

4. Do you know their limitations, useful life, disposal, and proper care?

_____ no _____ yes

5. How much protection does your PPE provide to your workplace environment? (circle one)

0 1 2 3 4 5

Poorly Very

**Please answer all of the following questions about employee right to know. (circle one).**

**Thank you for your participation.**

# APPENDIX H. IRB CONSENT FORMS

# EMPLOYEE SURVEY

The purpose of this survey is to secure feedback in the area of Hazard Communication. In order to make any changes to the current communication processes within your company, we need your input as you are the sole purpose for safety. This is a completely voluntary study. You may choose not to participate in the study and/or withdraw at any time. No form of punishment will be taken if you choose not to participate. All data gathered will be reported in aggregate form and no individual data will be revealed. Only the principal investigators will have access to the completed instruments.

All employees will be provided a self-administered survey instrument.

If you have any questions regarding the scope or reason for this study feel free to contact Paul Durand at 744-6055. He would be glad to clarify any points of interest. Thank you for your help in assisting your company with improving the teaching of employees in your company.

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Concerns about this project may be directed to Gay Clarkson, IRB Office, 305b Whitehurst, 744-5700.

# Mental Modeling a Hazard Communication Program

## Consent Form

You will be asked to define and construct a Hazard Communication Program, its relative components, and the current implementation practices of this program in your workplace. This study should last no longer than 30 minutes and is completely voluntary. Your confidentiality will be maintained by preventing anyone in your company, besides the researcher, to see any record of your participation. All records of involvement will be destroyed upon completion of this study.

You may withdraw from this study at anytime should you feel discomforted in anyway. Your input will be benefiting your company and society by examining the fundamental problems with current teaching practices concerning Hazard Communications. Your data will allow a model to be constructed which will show gaps in the current methods employed by companies to inform employees of their *right-to-know*.

This is done as a part of an investigation entitle "Determining the Effectiveness of Hazard Communication programs at Four Oklahoma Companies." Your participation is completely voluntary, that you may refuse to participate at anytime, and that you are free to withdraw the consent and participation in this project at anytime.

You are free to contact Paul Durand at telephone number (405)744-6055 should you have any further questions regarding this study. You may also contact Jennifer Moore, IRB Executive Secretary, 305 Whitehurst, Oklahoma State University, Stillwater, OK 74078; Telephone: (405)744-5700 should additional questions arise concerning this study or your wish to withdraw.

You have read and fully understand the consent form and a copy was provided. Your participation is completely voluntary and you sign it freely.

Date: _____ Time: _____ (a.m./p.m.)

Signed: _____

Signature of Participant

I confirm that the designated participant has read this statement and all questions were fully answered before requesting the subject to sign it.

Signed: _____

Researcher

# APPENDIX I. DATA COMPILED FROM COMPANY A

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Job Title** | Tech | Tech | Tech | Tech | Tech | Tech | Tech | Tech | Tech | Tech | Tech | Tech | Tech | Tech | Tech | Tech | Prod | Prod | Prod | Prod |
| **Duration** | 7 | 8 | 8 | 7.5 | 4 | 9 | 9 | 9 | 7 | 9 | 9 | 7 | 8 | 9 | 7 | 6.75 | 5 | 9 | | 3.5 |
| **ERTK Q: 1** | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| **2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| **3** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| **4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **5** | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| **6** | 2 | 0 | 1 | 2 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 2 | 1 | 1 | 1 |
| **7** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **8** | 5 | 3 | 3 | 5 | 3 | 4 | 3 | 2 | 4 | 3 | 4 | 3 | 4 | 2 | 3 | 1 | 3 | 5 | 0 | 5 |
| **9** | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| **10** | 2 | 1 | 1 | 4 | 5 | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 5 | 3 | 1 | 0 | 3 | 3 | 3 | 3 |
| **11** | 3 | 2 | 3 | 4 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 4 | 5 | 4 | 1 | 0 | 3 | 2 | 3 | 3 |
| **Co. rating: 1** | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **2** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| **3** | 4 | 4 | 5 | 4 | 5 | 4 | 5 | 3 | 5 | 3 | 5 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 1 | 5 |
| **4** | 4 | 5 | 5 | 3 | 4 | 3 | 4 | 3 | 5 | 4 | 5 | 3 | 5 | 4 | 4 | 2 | 5 | 5 | 2 | 5 |
| **PPE: 1** | 4 | 3 | 3 | 4 | 4 | 5 | 2 | 4 | 4 | 5 | 4 | 5 | 5 | 5 | 3 | 4 | 4 | 5 | 3 | 5 |
| **2** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **3** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **4** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| **5** | 5 | 4 | 4 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 5 | 4 | 3 | 3 | 3 | 5 | 3 | 5 |
| **ERTK Test: 1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| **2** | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **4** | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **5** | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| **6** | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| **7** | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **8** | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
| **9** | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| **10** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| **Score (%)** | 0.5 | 0.8 | 0.7 | 0.6 | 0.6 | 0.8 | 0.7 | 0.4 | 0.6 | 0.7 | 0.6 | 0.7 | 0.7 | 0.6 | 0.6 | 0.4 | 0.7 | 0.4 | 0.7 | 0.3 |

| Prod. | Prod. | Prod. | Prod | Prod | Prod | Press | Press | Press | Press | Press | Press | Press | Gel Line | Gel Line | Gel Line | C&F | C&F | C&F | C&F | C&F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 9 | 7.5 | 1 | 6.5 | 2.5 | 4 | 9 | 9 | 9 | 8 | 8 | 8 | 3 | 4.5 | 9 | 6 | 9 | 3 | 7.5 | 12 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 0 | 1 | 1 | 2 | 2 | 1 | 1 | 0 | 1 | 2 | 2 | 2 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3 | 4 | 1 | 3 | 4 | 4 | 5 | 0 | 3 | 5 | 5 | 4 | 4 | 2 | 3 | 3 | 4 | 3 | 3 | 2 | 3 |
| 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 4 | 4 | 1 | 1 | 1 | 3 | 5 | 5 | 1 | 3 | 3 | 3 | 1 | 3 | 4 | 1 | 1 | 1 | 0 | 1 |
| 4 | 4 | 4 | 1 | 2 | 3 | 3 | 5 | 4 | 1 | 3 | 3 | 3 | 2 | 3 | 4 | 1 | 2 | 1 | 1 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 4 | 4 | 3 | 4 | 3 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 2 | 1 | 4 | 2 | 5 | 2 | 4 |
| 5 | 5 | 4 | 4 | 4 | 5 | 4 | 3 | 5 | 2 | 5 | 4 | 4 | 3 | 2 | 1 | 4 | 3 | 5 | 2 | 4 |
| 5 | 5 | 4 | 5 | 4 | 5 | 5 | 3 | 5 | 5 | 5 | 5 | 3 | 5 | 1 | 3 | 5 | 4 | 4 | 5 | 5 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 4 | 5 | 3 | 5 | 4 | 5 | 4 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0.2 | 0.7 | 0.5 | 0.6 | 0.9 | 0.7 | 0.7 | 0.5 | 0.7 | 0.8 | 0.7 | 0.8 | 0.7 | 0.3 | 0 | 0.6 | 0.6 | 0.2 | 0.3 | 0.6 | 0.6 |

| C&F | C&F | C&F | C&F | C&F | C&F | C&F | C&F | Gel Line | Gel Line | Gel Line | Gel Line | Warehous | Warehous | Warehous | Warehous | Assembler | DC Loade | Dist. Ctr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 8.5 | 7.5 | 6 | 5.5 | 4.5 | 6 | 8 | 8 | 1 | 8 | 4.5 | 8.5 | 9 | 8.5 | 8 | 8 | 6 | 8.5 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | 4 | 2 | 0 | 3 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 4 | 4 | 2 | 5 | 2 | 4 | 2 | 2 | 3 | 3 | 5 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 1 | 3 | 2 | 2 | 1 | 2 | 2 | 2 | 0 | 1 | 0 | 3 | 1 | 5 | 0 | 4 | 3 | 3 | 4 |
| 1 | 1 | 2 | 4 | 1 | 2 | 2 | 2 | 3 | 1 | 4 | 3 | 1 | 5 | 5 | 3 | 1 | 2 | 2 |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 4 | 4 | 4 | 4 | 4 | 5 | 3 | 4 | 3 | 5 | 5 | 3 | 5 | 5 | 5 | 5 | 4 | 1 | 5 |
| 4 | 5 | 4 | 4 | 4 | 5 | 2 | 4 | 3 | 5 | 5 | 4 | 4 | 5 | 5 | 5 | 4 | 2 | 4 |
| 5 | 0 | 4 | 4 | 5 | 4 | 2 | 3 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 4 | 4 | 5 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| 5 | 3 | 4 | 4 | 4 | 4 | 3 | 3 | 1 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0.7 | 0.6 | 0.5 | 0.7 | 0.7 | 0.5 | 0.7 | 0.6 | 0.8 | 0.6 | 0.1 | 0.7 | 0.7 | 0.6 | 0.5 | 0.5 | 0.8 | 0.6 | 0.7 |

| DOT | Secretary | Plant Mgr. | Info Asst. | Info Asst. | Info Mgr. | Buyer | Stocker | DC | DC | DC | DC | DC | Print Line | Print Line | Loader | * | * | * | * | * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 7 | 25 | 8.5 | 8 | 8.5 | 9 | 8 | 3 | 8 | 3 | 7 | 9.5 | 9 | 6 | 3 | 2.5 | 9.5 | 7 | 8 | |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3 | 4 | 4 | 4 | 2 | 1 | 3 | 4 | 4 | 3 | 3 | 4 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 1 | 1 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 3 | 4 | 3 | 4 | 5 | 3 | 5 | 5 | 3 | 2 | 2 | 0 | 1 | 3 |
| 4 | 0 | 1 | 1 | 0 | 0 | 0 | 3 | 2 | 3 | 1 | 3 | 3 | 3 | 5 | 3 | 2 | 2 | 0 | 1 | 3 |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 4 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 3 | 5 | 5 | 4 | 3 | 4 | 4 | 4 | 3 | 5 | 4 | 2 | 3 |
| 4 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 3 | 5 | 5 | 4 | 2 | 4 | 3 | 4 | 3 | 4 | 4 | 2 | 4 |
| 5 | | 5 | 5 | | | | 3 | 5 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 3 | 5 | 3 | 3 |
| 0 | | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1 | | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 4 | | 5 | 4 | | | | 3 | 4 | 5 | 3 | 4 | 3 | 4 | 5 | 4 | 3 | 4 | 4 | 2 | 3 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0.4 | 0.6 | 0.6 | 0.5 | 0.7 | 0.9 | 0.7 | 0.8 | 0.6 | 0.7 | 0.8 | 0.6 | 0.6 | 0.5 | 0.3 | 0.6 | 0.8 | 0.7 | 0.6 | 1 | 0.7 |

| * | * | * | * | * | * | * | * | * |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 8 |
| 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 | 2 | 0 | 1 | 1 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5 | 4 | 5 | 3 | 4 | 3 | 3 | 3 | 5 |
| 1 | 0 | 1 | | 0 | 0 | 1 | 0 | 0 |
| 3 | | | | 2 | 3 | 3 | 2 | 2 |
| 2 | | | | 2 | 3 | 3 | 1 | 2 |
| 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 4 | 5 | 2 | 4 | 4 | 4 | 4 | 4 | 5 |
| 5 | 5 | 2 | 4 | 4 | 3 | 3 | 4 | 4 |
| 3 | 4 | 0 | 5 | 3 | 4 | 3 | 2 | 5 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| 4 | 4 | 1 | 3 | 4 | 3 | 3 | 3 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| 0.5 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.7 |

# APPENDIX J. DATA COMPILED FROM COMPANY B

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Job Title** | Operato | Operato | Operato | Operato | Operato | Operato | Operato | Operato | Operato | Operato | Operato | Operato | Operator | Operator | Operator | Operator | Operato | Maint | Maint |
| **Duration** | 25 | 18 | 1 | 13 | 9 | 19 | 10 | 5 | 29 | 23 | 10 | 25 | 31 | 11 | 2 | 13 | 0.5 | 19 | 19 |
| **ERTK Q: 1** | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **3** | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **5** | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| **6** | 1 | 0 | 0 | 2 | 2 | 0 | 3 | 2 | 0 | 3 | 2 | 1 | 3 | 2 | 2 | 1 | 2 | 2 | 1 |
| **7** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **8** | 4 | 3 | 2 | 5 | 5 | 3 | 4 | 5 | 3 | 3 | 4 | 3 | 4 | 5 | 5 | 4 | 5 | 4 | 3 |
| **9** | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **10** | 2 | 1 | 2 | 5 | 5 | 3 | 5 | 2 | 1 | 3 | 2 | 2 | 5 | 4 | 3 | 4 | 4 | 4 | 2 |
| **11** | 2 | 1 | 3 | 5 | 5 | 3 | 3 | 1 | 3 | 3 | 2 | 2 | 4 | 2 | 3 | 2 | 4 | 4 | 2 |
| **Co. rating: 1** | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| **2** | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| **3** | 4 | 4 | 5 | 5 | 5 | 4 | 4 | 5 | 5 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 |
| **4** | 4 | 3 | 4 | 5 | 5 | 4 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 5 | 4 | 5 |
| **PPE: 1** | 4 | 4 | 0 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 | 5 | | 5 | 5 | |
| **2** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | | 0 | 0 | 0 |
| **3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | 1 |
| **4** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | 1 |
| **5** | 4 | 4 | 4 | 5 | 5 | 3 | 3 | 4 | 5 | 4 | 4 | 5 | 4 | 5 | 4 | | 4 | 4 | 5 |
| **ERTK Test: 1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **2** | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| **3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **4** | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| **5** | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **6** | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| **7** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **8** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **9** | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| **10** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Score (%)** | 0.8 | 0.7 | 0.6 | 0.9 | 0.7 | 0.7 | 0.9 | 0.5 | 0.7 | 0.8 | 0.6 | 0.6 | 0.7 | 0.8 | 0.7 | 0.8 | 0.9 | 0.9 | 0.6 |

| Maint | Maint | Maint | Maint | ab Tec | ab Tec | ab Tec | ab Tec | Manage | Manage | Manage | Coater | chedule | rod/Inve | oordinat | * | * | * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4.5 | 12 | 12 | 10 | 30 | 9 | 13 | 13 | 11 | 29 | 1 | 18 | 11 | 20 | 8 | 9 | |
| 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 2 | 0 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 0 | 2 | 2 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 4 | 5 | 4 | 3 | 5 | 4 | 3 | 5 | 5 | 5 | 3 | 3 | 2 | 4 | 5 | 0 | 3 | 4 |
| 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| 3 | 4 | 5 | 5 | 5 | 2 | 1 | 5 | 2 | 4 | 3 | 3 | 0 | 4 | 2 | 3 | | 0 |
| 4 | 5 | 5 | 5 | 4 | 2 | 1 | 3 | 2 | 4 | 2 | 3 | 0 | 2 | 2 | 5 | 2 | 1 |
| 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 5 | 4 | 3 | 5 | 5 | 5 | 5 | 4 | 3 | 4 | 5 | 4 | 2 | 5 | 0 | 5 | 5 |
| 3 | 5 | 4 | 3 | 5 | 5 | 5 | 5 | 4 | 3 | 4 | 5 | 3 | 2 | 5 | 0 | 4 | 4 |
| 5 | 4 | 5 | 4 | 5 | 5 | 1 | 5 | 3 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 5 |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 5 | 5 | 4 | 4 | 4 | 3 | 3 | 5 | 4 | 5 | 4 | 4 | 3 | 4 | 4 | 5 | 5 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0.9 | 0.8 | 0.5 | 0.8 | 0.8 | 0.7 | 0.8 | 0.9 | 0.8 | 0.8 | 0.8 | 0.8 | 0.6 | 0.7 | 0.8 | 0.8 | 0.8 | 0.7 |

# APPENDIX K. DATA COMPILED FROM COMPANY C

| Job Title | | Sup. | Line Op. | PMP Op | PMP Op | PMP Op | Line Op. | 29 Line | 29 Op. | 39 Line | 39 Line | Rod Mill | 58 Line | 58 Line | Rod Mill | Rod Mill | Tech. | MP Coo | 70 Line | Shipper |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Duration | | 22 | 2 | 4 | 2.5 | 2 | 5 | 13 | 3.5 | 2.2 | 1.9 | 3 | 4 | 2 | 4 | 0.2 | 3 | 14 | 14 | 12 |
| ERTK Q: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 0 | 0 | 2 | 1 | 0 | 1 | 1 | 2 | 2 | 1 | 1 | 2 |
| | 3 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| | 5 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| | 6 | 2 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 |
| | 7 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| | 8 | 2 | 3 | 0 | 3 | 3 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 0 | 5 | 5 | 4 | 3 | 2 |
| | 9 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| | 10 | 5 | 4 | 1 | 4 | 1 | 4 | 5 | 3 | 5 | 4 | 5 | 5 | 3 | 3 | 1 | 4 | 1 | 3 | 0 |
| | 11 | 1 | | 1 | 4 | 2 | 5 | 3 | 4 | 4 | 3 | 4 | 5 | | 3 | 2 | 3 | 3 | 3 | 0 |
| Co. rating: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| | 2 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| | 3 | 5 | 5 | 4 | 5 | 5 | 4 | 3 | 4 | 4 | 4 | 5 | 3 | 3 | 2 | 5 | 5 | 4 | 2 | 3 |
| | 4 | 5 | 4 | 4 | 2 | 5 | 2 | 4 | 3 | 4 | 4 | 5 | 2 | 4 | | 5 | 5 | 3 | 3 | 3 |
| PPE: | 1 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 1 | 4 | 5 | 5 | 1 | 3 | 5 | | 5 | 4 | 4 | 3 |
| | 2 | 0 | 0 | 1 | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| | 5 | 5 | 5 | 4 | 3 | 5 | 3 | 5 | 4 | 4 | 4 | 5 | 4 | 4 | 3 | 5 | 5 | 4 | | 5 |
| ERTK Test: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| | 3 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| | 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 6 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| | 7 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 9 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| | 10 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Score (%) | | 0.5 | 0.7 | 0.5 | 0.6 | 0.8 | 0.6 | 0.5 | 0.7 | 0.6 | 0.8 | 0.5 | 0.5 | 0.8 | 0.7 | 0.5 | 0.8 | 0.7 | 0.4 | 0.8 |

| Maint. | * | PMP | Rod Mill | hift Sup | * | Rod Mill | Rod Mill | Rod Mill | 39 Line | Line Op. | 29 Line | 39 Line | 29 Line | 39 Line | 58 Line | ill Coor | 58 Line | ie Rea | 29 Line |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | | 10 | 12.5 | 20 | 0.2 | 2 | 13 | 1.8 | 4 | 2.5 | 3 | 12 | 2 | 3 | 10 | 1.9 | | 1 |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| 1 | 2 | 0 | 1 | 1 | 0 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 0 | 2 |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3 | 0 | 3 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 0 | 2 | 2 | 4 | 4 | | 3 | 5 | 4 | 3 | 5 | 1 | 1 | 5 | 3 | 5 | 4 | 0 | 4 | 4 |
| 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| 4 | 4 | 5 | 1 | 3 | 0 | 1 | 5 | 1 | 4 | 5 | 4 | 5 | 4 | 5 | 5 | 4 | 4 | 2 | 4 |
| 4 | 1 | 5 | 3 | 3 | | 1 | 5 | 4 | 3 | 5 | 4 | 5 | 4 | 4 | 5 | 4 | 2 | 3 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 0 |
| 0 | 3 | 2 | 3 | 3 | 3 | 4 | 5 | 5 | 4 | 2 | 2 | 4 | 5 | 4 | 3 | 3 | 5 | 1 | 4 |
| 1 | 0 | 1 | 3 | 3 | 3 | 4 | 5 | 4 | 4 | 1 | 2 | 5 | 4 | 3 | 3 | 4 | 5 | 5 | 4 |
| 4 | 3 | 4 | 4 | 3 | 0 | 0 | 5 | 5 | 4 | 5 | 3 | 5 | 5 | 4 | 5 | 3 | 5 | 0 | 5 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 2 | 5 | 2 | 5 | 4 | 5 | 3 | 5 | 3 | 4 | 4 | 3 | 5 | 5 | 3 | 3 | 3 | 4 | 5 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| 0.5 | 0.4 | 0.6 | 0.8 | 0.7 | 0.6 | 0.7 | 0.3 | 0.4 | 0.7 | 0.4 | 0.6 | 0.5 | 0.5 | 0.5 | 0.7 | 0.7 | 0.5 | 0.4 | 0.6 |

| 39 Line | Operato | 39 Line | 29 Line | 29 Line | 29 Line | Mill Coord | Sup. | Enginee | Prod Mg | PMP Op | * | Enginee | Maint. | Asst Foreman | Operato | Rod Mill | Mill |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3 | 2 | 2.8 | 2 | 3.5 | 8 | 13 | 0.9 | 7 | 15 | | 0.9 | 23 | 16 | 13 | 3 | 6 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 2 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 4 | 0 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 1 |
| 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| 3 | 2 | 4 | 3 | 4 | 2 | 2 | 4 | 5 | 2 | 3 | 4 | 2 | 4 | 3 | 1 | 0 | 2 |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 |
| 3 | 4 | 5 | 3 | 4 | 4 | 2 | 3 | 1 | 3 | 0 | 3 | 2 | 3 | 1 | 5 | 1 | 2 |
| 3 | 5 | 5 | 3 | 3 | 5 | 2 | 3 | 0 | 3 | 0 | 3 | 3 | 4 | 3 | 3 | 3 | 4 |
| 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 3 | 3 | 4 | 4 | 3 | 4 | 5 | 4 | 3 | 4 | 2 | 4 | 5 | 1 | 4 | 2 | 1 | 2 |
| 4 | 3 | 3 | 4 | 3 | 1 | 4 | 4 | 4 | 5 | 2 | 4 | 5 | 3 | 4 | 2 | 1 | 3 |
| 5 | 4 | 4 | 5 | 4 | 3 | 4 | 5 | 4 | 4 | 5 | 3 | | 2 | 4 | 1 | 2 | 4 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 4 | 4 | 2 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | 3 | 1 | 3 | 4 |
| 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 0.5 | 0 | 0.4 | 0.4 | 0.6 | 0.4 | 0.6 | 0.6 | 0.7 | 0.5 | 0.5 | 0.6 | 0.9 | 0.5 | 0.8 | 0.3 | 0.4 | 0.6 |