Risk encompasses impacts on public health and on the environment, and arises from *exposure* and *hazard*. Risk does not exist if exposure to a harmful substance or situation does not or will not occur. Hazard is determined by whether a particular substance or situation has the potential to cause harmful effects.

MAKING A HAZARD ANALYSIS/RISK ASSESSMENT

For many hazards and the risks that derive from them, knowledge gained by safety professionals through education and experience will lead to proper conclusions on how to attain an acceptable risk level without bringing teams of people together for discussion. For the more complex situations, it is vital to seek the counsel of experienced personnel who are familiar with the work or process. Reaching group consensus is a highly desirable goal. Sometimes, for what a safety professional considers obvious, achieving consensus is still desirable so that buy-in is obtained for the actions to be taken. A general guide follows on how to make a hazard analysis and how to extend the process into a risk assessment.

This guide is applicable to every phase of the life cycle of facilities, equipment, processes, and materials (e.g., design, construction, operation, maintenance, and disposal).

Whatever the simplicity or complexity of the hazard/risk situation, and whatever analysis method is used, the following thought and action process is applicable.

A Hazard Analysis and Risk Assessment Guide.

1. **Select a risk assessment matrix.** A risk assessment matrix provides a method to categorize combinations of probability and severity, thus establishing risk levels. A matrix helps in communicating with decision makers and influencing their decisions on risks and the actions to be taken to ameliorate them. Also, risk assessment matrices can be used to compare and prioritize risks and to effectively allocate mitigation resources.

   Definitions of the levels of probability and severity used in risk assessment matrices vary greatly. That reflects the differences in the perceptions people have of risk. Since a risk assessment matrix is a management decision tool, management personnel at appropriate levels must agree on the definitions of the terms to be used. In so doing, management establishes the levels of risk that require reduction and those that are acceptable.

   Repeating for emphasis: Safety professionals must understand that definitions of terms for incident probability and severity and for risk levels vary greatly. Thus, they should tailor a risk assessment matrix to suit the hazards and risks and the management tolerance for risk with which they deal. Examples of definitions used for incident probability and severity are presented here as well as for risk categories and risk assessment matrices.

They are to provide safety professionals with a broad base of information from which choices can be made in developing the matrix considered appropriate for their clients' needs.

The breadth of possibilities in drafting a risk assessment matrix is extensive. Matrices have been developed that display only one or a combination of several of the following injury or damage classes: employees, members of the public, facilities, equipment, product, operation downtime, and the environment.

For this primer, two-dimensional risk assessment matrices are discussed. They are displays of variations for two categories of terms: the *severity* of harm or damage that could result from a hazards-related incident or exposure, and the *probability* that the incident or exposure could occur. They also show the *risk levels* that derive from the various combinations of severity and probability.

A review of three-and four-dimensional risk assessment systems is given in Chapter 13, "Three and Four Dimensional Numerical Risk Scoring Systems".

2. **Establish the analysis parameters.** Select a manageable task, system, process, or product to be analyzed, establish its boundaries and operating phase (standard operation, maintenance, startup), and define its interface with other tasks or systems, if appropriate. Determine the scope of the analysis in terms of what can be harmed or damaged: people (the public, employees), property, equipment, productivity, the environment.
3. **Identify the hazards.** A frame of thinking should be adopted that gets to the bases of causal factors, which are hazards. These questions would be asked: What are the aspects of technology or activity that produces risk? What are the characteristics of things or the actions or inactions of people that present a potential for harm? Depending on the complexity of the hazardous situation, some or all of the following may apply.
   - Use intuitive engineering and operational sense: This is paramount throughout.
   - Examine system specifications and expectations.
   - Review codes, regulations, and consensus standards.
   - Interview current or intended system users or operators.
   - Consult checklists.
   - Review studies from similar systems.
   - Consider the potential for unwanted energy releases.
   - Take into account possible exposures to hazardous environments.
   - Review historical data: industry experience, incident investigation reports, OSHA and National Safety Council data, manufacturers' literature.
   - Brainstorm.

4. **Consider the failure modes.** Define the possible failure modes that would result in realization of the potentials of hazards. Ask: What circumstances can arise that would result in the occurrence of an undesirable event? What controls are in place that mitigate against the occurrence of such an event or exposure? How effective are the controls?
5. **Determine the frequency and duration of exposure.** For each harm or damage category selected for the analysis (people, property, business interruption, etc.), estimate the frequency and duration of exposure to the hazard. This is a very important part of this exercise. For example, in a workplace situation, ask: How often is a task performed, how long is the exposure period, and how many people are exposed? More judgments than one might realize will be made in this process.
6. **Assess the severity of consequences.** The purpose is to determine the magnitude of harm or damage that could result. Informed speculations are made to establish the consequences of an incident or exposure: the number injuries or illnesses and their severity, and fatalities; the value of property or equipment damaged; the time for which productivity will be lost; and the extent of environmental damage. Historical data can be of value as a baseline but should not be treated as the primary or sole determinant. Judgment of knowledgeable and competent personnel should prevail.

   On a subjective basis, the goal is to decide on the worst credible consequences should an incident or exposure occur, not the worst conceivable consequence.

   When the severity of the outcome of a hazard-related incident or exposure is determined, a hazard analysis has been completed.

7. **Determine occurrence probability.** Extending the hazard analysis into a risk assessment requires the one additional step of estimating the likelihood, the probability, of a hazardous event or exposure occurring. Unless empirical data are available, and that would be a rarity, the process of selecting incident or exposure probability is subjective. As is the case when determining severity of consequences, historical data can be of value as a baseline but should not be the sole determinant. Judgment of knowledgeable and competent personnel, controls in place and their capability, and lessons learned with respect to similar systems should prevail.

   For the more complex hazardous situations, it should be considered a necessity that brainstorming sessions be held with knowledgeable people and that consensus be reached in determining occurrence probability.

   To be meaningful, probability has to be related to an interval base of some sort, such as a unit of time or activity, events, units produced, or the life cycle of a facility, equipment, process, or a product.
8. **Define the initial risk.** Conclude with a statement that addresses the probability of a hazard-related incident or exposure occurring, the expected severity of

adverse results, and a risk category (e.g., – high, serious, moderate, or low). Using a risk assessment matrix for that purpose assists in communicating on the risk level.

9. **Risk prioritization.** A risk ranking system should be adopted so that priorities can be established. Since the risk assessment exercise is subjective, the risk ranking system would also be subjective. Prioritizing risks gives management the knowledge needed for intelligent allocation of resources with respect to risk avoidance, elimination, or control.
10. **Select and implement risk reduction and control methods.** When the initial risk assessment indicates that elimination or reduction measures are to be taken to achieve acceptable risk levels:
    - Alternative proposals for the design and operational changes necessary would be recommended.
    - In their order of effectiveness, the actions outlined in Chapter 14, "Hierarchy of Controls", would be the basis upon which remedial proposals are made.
    - If informal judgments on costs are considered inadequate for a risk situation, formal action would be taken to establish remediation cost for each proposal and an estimate would be given of its effectiveness in achieving risk reduction to an acceptable risk level.
    - Risk avoidance, elimination, or reduction methods would be selected and implemented.
    - A tracking system should be put in place to assure completion of the actions undertaken.
11. **Assess the residual risk.** *Residual risk* is defined as the risk remaining after preventive measures have been taken. No matter how effective the preventive actions, there will always be residual risk if a facility exists or an activity continues. Attaining zero risk is not possible.
    - If the residual risk is not acceptable, the action outline set forth in this hazard analysis and risk assessment process would be applied again.
    - The risk assessment process is to continue until an acceptable risk level is attained.
    - If an acceptable risk level cannot be achieved, operations should not be continued, except in unusual and emergency circumstances or as a closely monitored and limited exception and with the approval of the person who has the authority to accept the risk.
    - Information on residual risks is to be communicated to relevant downstream stakeholders so that they can use this information in their own risk assessments.

    Even though the residual risk may be acceptable, management should consider taking additional risk reduction measures if the cost is reasonable, particularly if so doing resolves concerns of employees.