Severe Injury Potential

Addressing an often-overlooked safety management element

By Fred A. Manuele

SOME SAFETY PRACTITIONERS PRESUME that efforts focused on the types of accidents which occur frequently will also encompass the types of accidents that result in severe injury or damage. That premise is a reflection of H.W. Heinrich's belief, stated in the first edition of *Industrial Accident Prevention: A Scientific Approach,* that "the predominant causes of no-injury accidents are identical with the predominant causes of accidents resulting in major injuries" (90). Heinrich carried this idea forward in the later editions of his book.

But a differing observation has been made by some safety professionals—that incidents resulting in severe injury or damage are, mostly, unique and singular events; that their causal factors are different than those for accidents that result in minor injury; and that preventing their occurrence requires special safety management techniques.

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In "Occupational Injuries: Factors Associated With Frequency and Severity," D. Kriebel offers these observations about the relation between injury frequency and severity.

> A Model of Injury Severity: Safety researchers have generally ignored severity, perhaps because for many years it was believed that the seriousness of the consequences of an accident was essentially randomly determined (Heinrich 1959). However, the analysis of the data from 89 industries (studied) . . . shows that the frequency and average severity of the injuries in an industry are poorly correlated one to the other, and are essentially independently determined (212).

In *MORT Safety Assurance Systems,* William Johnson also implies that severity potential needs greater emphasis.

> Some safety professionals are overly concerned with winning awards for reductions in minor injuries and underemphasize sources of serious accidents and disasters. Such a tendency can mislead management (19).

Can Serious Injury Potential Be Identified?

To a considerable degree, the answer to this question is yes. One can identify the types of work which produce many accidents that result in serious injury; then, the relevant hazards in that work can be addressed on an anticipatory basis. Although data in support of this premise are limited, it is persuasive. For example, in the second edition of *Safety Management,* Dan Petersen writes:

> If we study any mass data, we can readily see that the types of accidents that result in temporary total disabilities are different from the types of accidents resulting in permanent partial disabilities or in permanent total disabili-

> ties or fatalities. The causes are different. There are different sets of circumstances surrounding severity. Thus, if we want to control serious injuries, we should try to predict where they will happen. Today, we can often do just that.
>
> Studies in recent years suggest that severe injuries are fairly predictable in certain situations. Some of those situations involve:
> - unusual, nonroutine work;
> - nonproduction activities;
> - sources of high energy;
> - certain construction situations.
>
> These are just a beginning point. A long list could be made which would more extensively specify the areas where severity is predictable (11).

Data, not yet published and provided by Franklin Mirer, director of the Health and Safety Dept. at the International Union-UAW, is in concert with Petersen's observations. The data indicate that severe injury accidents occur disproportionately in unusual and nonroutine work, in nonproduction activities and where high sources of energy are present. During the 18 years prior to Jan. 1, 2002, the data show that skilled trades people—who represent about 20 percent of the UAW work population of about 700,000—make up 40 to 50 percent of the fatalities. These individuals include maintenance personnel, millwrights, electricians, steamfitters and tinsmiths; they rarely engage in repetitive and routine work, nor do they engage in production work. Total hours worked by the UAW population over this period is in the billions, which represents a sound statistical base; these data have significance.

The safety director of a chemical company notes that when the system is running, the risks are lower; when the system must be opened for maintenance or equipment fails or a chemical release occurs, severity potential is greatly increased. A safety director for a heavy electrical equipment manufacturer says that severe injuries in his company rarely occur during routine production operations.

However, severe injury or damage potential does exist in routine production work, and that potential can also be identified. The purpose here is not to suggest diminishing efforts to prevent accidents that produce less-than-severe injuries. Rather, the intent is to encourage adoption of additional efforts to prevent accidents that result in severe injury.

Cascading Events: Accidents That Result in Serious Injury

What have others said about the nature of incidents that result in serious injury? In *The Psychology of Everyday Things,* Donald Norman asserts that "it is spectacularly easy to find examples of false assessment in industrial accidents." Norman teaches undergraduate and graduate classes entitled "Cognitive Engineering" at the University of California, San Diego. He writes:

> Explaining away errors is a common problem in commercial accidents. Most major accidents follow a series of breakdowns and errors, problem after problem, each making the next more likely. Seldom does a major accident occur without numerous failures: equipment malfunctions, unusual events, a series of apparently unrelated breakdowns and errors that culminate in major disaster; yet no single step has appeared to be serious. In many of these cases, the people involved noted the problem but explained it away, finding a logical explanation for the otherwise deviant observation (128).

Many accidents that result in severe injury are unique and singularly occurring events in which a series of breakdowns occur in a cascading effect.

Note the terminology "numerous failures" and "a series of apparently unrelated breakdowns and errors." An aspect of many incidents that result in severe injury is the cascading effect of multiple causal factors acting in sequence—sometimes in parallel sequences—toward an undesirable end. Kingsley Hendrick and Ludwig Benner Jr. offer similar comments about the cascading effect of events in accident occurrences in *Investigating Accidents With STEP.*

> Because accidents are composed of sets of individual events, all of which are interrelated, each event affects one or more actors and what they do next, changing their state. The first event in the accident process is a perturbation or an undesired or unplanned change in someone or something within the planned process. That first disruptive event initiates a sort of cascading effect, culminating in some harm or loss (31).

The term "actor" is used to identify the people or things who or which directly influenced the flow of events that construct the accident sequence (69). STEP is an acronym for "sequentially timed events plotting." It is an events-analysis-based approach in which events are plotted sequentially (and in parallel, if appropriate) to show the cascading effect as each event impacts on others. It is built on the management system embodied in the management oversight and risk tree (MORT) and system safety technology.

Having been involved in many incident investigations and having reviewed thousands of accident reports, the author concludes that many accidents which result in severe injury are unique and singularly occurring events in which a series of breakdowns occur in a cascading effect. That phenomenon calls for creating and implementing methods that identify serious injury potentials and mitigate against their occurrence. Preventing such accidents requires a strategy that specifically addresses serious injury potential in every aspect of safety management—from initial design through dismantling and disposition.

Risk Avoidance & Control in the Design Process

Avoiding serious injury potential is most effec-

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tively accomplished in the original design process, although redesign activities (applying the same safety-through-design principles) present similar opportunities when retrofitting occurs. The auto industry provides an example of methods to be used to avoid injury potential—particularly serious injury potential—both in the initial design and subsequent redesign processes. Although the following excerpt is taken from the 1999 General Motors/UAW labor agreement, similar language appears in such contracts with other auto companies.

> As early as possible and preferably in the zero phase of the planning in the design process . . . the parties agree to perform task-based risk assessments on new equipment and manufacturing systems, and on existing equipment and manufacturing systems where locally agreed to and approved by the Plant Safety Review Board. A task-based risk assessment will be performed after the detailed designs are completed. . . . A review of anticipated equipment and/or processes with the shop committee and the Local Joint Health and Safety Committee will be held.
>
> The Local Joint Health and Safety Committee may be required to travel to vendors, plants or other locations to participate in a design review of such equipment or processes as outlined in the Design for Health and Safety Specification.
>
> Machinery, equipment or processes will not be released for production without the written approval of the plant safety administrator.

In summary, this agreement presents a theoretical ideal. If it became a model, universally applied, serious injury potential would be significantly reduced.

A Relevant European Guideline: Impacting Design & Operations Considerations

With respect to guidelines and standards that include provisions applicable to the prevention of accidents which result in severe injuries or fatalities, this author believes that the Europeans are the world's leaders. Little safety literature applies specifically to severe injury potential. One exception is "Guidelines on a Major Accident Prevention Policy and Safety Management System as Required by Council Directive 96/82/EC (Seveso II)" (which can be found at http://mahbsrv.jrc.it/NewProducts-SafetyManagementSystems.html).

This document was issued by the European Commission-Joint Research Centre, Institute for Systems Information and Safety, Major Accident Hazards Bureau. It reflects the intent of Council Directive 96/82/EC (SEVESO II) which "is aimed at the prevention of major accidents involving dangerous substances and the limitation of their consequences." The document features four major sections: introduction to safety management systems; development of major accident prevention policy; elements of safety management systems; and bibliography.

In particular, the section on elements of safety management systems speaks to the topic at hand. It contains these subsections: organization and personnel; hazard identification and evaluation; operational control; management of change; planning for emergencies; monitoring performance; and audit and review. While all of these elements are significant in avoiding severe-injury-producing accidents, the subsection on hazard identification and evaluation is particularly relevant. It requires hazard and risk identification and avoidance or mitigation, both on an anticipatory basis in the design process and during all phases of operations. It reads:

> The following issues shall be addressed by the safety management system (SMS): identification and evaluation of major hazards—adoption and implementation of procedures for systematically identifying major hazards arising out of normal and abnormal operation and the assessment of their likelihood and severity.

The following excerpts, taken from the text that follows the citation above, specify the actions to be taken with respect to major hazards.

> Hazard identification and evaluation procedures should be applied to all relevant stages from project conception through to decommissioning, including:
>
> •potential hazards arising from or identified in the course of planning, design, engineering, construction, commissioning and development activities;
>
> •the normal range of process operating conditions, hazards of routine operations and nonroutine situations, in particular start-up, maintenance and shut down.

Thus, these requirements encompass identifying hazards and risks both on an anticipatory basis in the design process and in the entire spectrum of operations. That is vital in minimizing severe injury potential. If no hazards are present—no potential for harm—no accidents can occur.

A companion piece to the guidelines is the book *Prevention of Major Industrial Accidents,* which is an International Labour Office "code of practice"; its content parallels the guidelines, but is more extensive.

OSHA & EPA

Although OSHA's Process Safety Management (PSM) standard and EPA's Risk Management Program (RMP) regulation could be considered to address severe injury potential, their terminology is not specifically so directed. OSHA 1910.119, which pertains to PSM of highly hazardous chemicals, contains provisions such as process hazard analysis, operating procedures, prestartup safety review, management of change, and emergency planning and response. Those provisions can be interpreted as serious injury prevention measures.

While OSHA's regulatory authority pertains to on-site consequences, EPA's concerns center on offsite consequences. EPA 40 CFR Part 68 mandates RMPs, which are designed to help prevent accidental chemical releases. It contains provisions for hazard reviews and control, and overlaps considerably with the PSM requirements. However, neither rule includes language similar to that found in the European guidelines with respect to potential hazards arising from or identified in the course of planning, design, engineering, construction, commissioning and development activities.

Other Prevention Techniques

In addition to the cited methods to avoid serious injury, other preventive techniques are available. Although the suggestion here is that the following techniques be adapted as specific measures to identify hazards that present serious injury potential, the methods can encompass the prevention of all types of incidents. The techniques are the critical incident technique and pre-job planning for nonroutine work.

The Critical Incident Technique

The critical incident technique is used to identify and take action on hazards that pose serious injury potential. Skilled observers interview a sampling of personnel, eliciting their recall of "critical" incidents which have exposed them to operational or physical hazards that caused them concern, whether or not injury occurred. For this process to succeed, those involved must recognize that workers being interviewed are a valuable resource in identifying hazards and risks because of their extensive knowledge of how the work is performed.

Critical incidents identified are analyzed and classified with respect to the significance of the risks presented by hazards identified, with priorities set for remedial action (Grimaldi and Simonds 248; NSC 101; Tarrants; Johnson 386). Johnson's comments on this technique are of particular interest. With respect to incident recall he writes:

> Incident recall is an information gathering technique whereby employees (participants)

Figure 1

Pre-Job Planning & Safety Analysis Outline

1) Review the scenario that defines the work to be done. Considering both safety and productivity:
   - a) Break down the job into manageable tasks.
   - b) Determine:
     - •how each task will be performed;
     - •in what order the tasks will be performed;
     - •what equipment or materials are needed;
     - •whether any particular skills are necessary.

2) Will the work require: a hot work permit, a confined space entry permit, lockout/tagout (of what equipment or machinery)?

3) Will it be necessary to barricade for clear work zones?

4) Will aerial lifts be required?

5) What PPE will be required?

6) Will fall protection be required?

7) What are the hazards in each task? Consider:

Fire	Explosion	Pressure
Work at heights	Work at depth	Vibration
Pinch points	Fall hazards	Electricity
Chemicals	Dusts	Noise
Weather	Sharp objects	Steam
Elevated loads	Stored energy	Dropping tools
Moving equipment	Forklifts	Hot objects
Conveyors	Access	Weight

These are examples only. A hazards list should be developed to suit the hazards and risks inherent in the operation.

8) Of the hazards identified, do any present severe risk of injury?

9) Develop hazard control measures, applying the safety decision hierarchy.
   - •Eliminate hazards and risks through system design and redesign.
   - •Reduce risks by substituting less-hazardous methods/materials.
   - •Incorporate safety devices (fixed guards, interlocks).
   - •Provide warning systems.
   - •Apply administrative controls (work methods, training, etc.).
   - •Provide personal protective equipment.

10) Is any special contingency planning necessary? People? Procedures?

11) What are workers to do if the work doesn't go as planned?

12) Considering the foregoing, are the risks acceptable? If not, what action should be taken?

Figure 2

Example Pre-Job Plan & Safety Analysis

Work to be performed: Install siding on the outside perimeter of the welding shop using a 40-ft. aerial work platform

Analysis prepared by: Irene Dunne, General Supervisor **Date:** 6/5/2002

Competent Person: T. Paine **Qualified Person:** H. Lee

Hazard	Safe Work Practices & Hazard Control	Contingency Plan
Falling from aerial work platform.	• Employees will utilize full-body harness with shock-absorbing lanyard attached to manufacturer's identified anchorage point in the aerial work platform. • Employees will be trained to use the aerial work platforms used on this project. Hard hat stickers will be issued and displayed on the hard hats of those trained. • At the beginning of each shift, the aerial work platform operator will perform a visual inspection and functional test according to the manufacturer's recommendation. A copy of the inspection and test will remain with the equipment for the entire shift.	Building phones are not available. When using a cell phone, the **emergency number is (123) 456-7890.**
Aerial work platform tipover (adjacent to an area of excavation work). Muddy ground conditions due to poor drainage may cause problems.	• Due to heavy rain and poor drainage it will be necessary to monitor and test the soil conditions and terrain surrounding the building in each new area and before work begins to ensure a safe foundation for the aerial work platform and mobile crane operations. Stable conditions will be provided, where necessary, through use of mudsill blocks, cribbing, or other acceptable means for effective wheel contact, outrigger placement and equipment support. • **T. Paine** will also be on the ground, rigging and attaching the siding panels. • **T. Paine** will inspect ground conditions on a daily basis and after any rain, paying close attention to areas around nearby excavations. • **T. Paine** will inspect the path of travel and ground conditions in each new area where the aerial work platform will be set up to install siding.	If workers in the aerial work platform are unable to operate the controls, the **competent** ground person, **T. Paine,** will begin a rescue by operating the ground controls. T. Paine is also trained in first aid and CPR.
Falling sheets of siding, materials or tools.	• Siding panels will be hoisted into fastening position by using a mobile crane and proper rigging technique. • Siding panels will be securely fastened before releasing the hoisting apparatus.	
Electrical shock.	• All electrical power tools and extension cords will be GFCI protected.	
People entering into the hazard work area.	• Portable 42-in. barricades will be used to deter entry of unauthorized personnel into the hazard area.	
Inclement weather conditions.	• Consideration will be given to weather-related conditions. If the wind, rain or storm conditions, or other situations regarding hazardous weather occur, this operation will be temporarily suspended.	
Persons falling from roof.	• Employees working on the roof will utilize full-body harnesses with shock-absorbing lanyards attached to the existing anchorage point(s). The capacities were verified by our P.E.	The qualified person for fall hazard control on this job is **H. Lee.**

describe situations they have personally witnessed involving good and bad practices and safe and unsafe conditions.

Such studies, whether by interview or questionnaire, have a proven capacity to generate a greater quantity of relevant, useful reports than other monitoring techniques, so much so as to suggest that their presence is an indispensable criterion of an excellent safety program (386).

Pre-Job Planning & Safety Reviews for Nonroutine Work

Based on the author's experience and review of incident reports on severe injuries resulting from accidents that occurred during nonroutine work, it can be said (at least anecdotally) that the work likely would not have been performed the way it was had a pre-job planning and safety review been conducted. And, while further inquiry suggests that pre-job safety reviews are not the norm in many companies, interest appears to be growing. Based on a study in Michigan, a report titled, "Risk Assessment for Maintenance Activities: Preventing Injuries Before They Happen" was issued in October 2001 and made available via the Internet in March 2002 (Main). In the two weeks following its posting, 375 downloads were recorded. The maintenance personnel included in the survey usually perform nonroutine work—and as noted, they experience a disproportionate share of the serious injuries and fatalities. Therefore, it appears that conducting pre-job safety reviews for nonroutine work would greatly reduce the risk of severe injury and fatality.

It should be noted that establishing the concept is what is most important. Care must be taken to not create extensive procedures and reports when that is not necessary for a particular and simplistic nonroutine job. For many such jobs, it is sufficient if the work planning and safety review conducted are simply brief discussions that allow those involved to arrive at a go or no-go conclusion. Ideally, it will become standard practice for workers to think through the job to be performed and to plan for the methods to be used, discuss the hazards and risks, and determine whether the risks are acceptable. Of course, if they conclude that the risks posed are not acceptable, a more thorough job review and risk assessment will be necessary.

Achieving a culture change that incorporates pre-job planning and safety analysis as an accepted and expected practice requires support from all levels of management and from workers. Such a change cannot be attained without training that helps workers understand the key concepts. As the following example demonstrates, this change can be achieved.

The Concept in Practice

At a large location, the severe injury experience was considered excessive for nonroutine work and needed to be addressed. As staff safety professionals prepared a course of action and talked it up with all personnel—from top management to hourly workers—they encountered the usual negatives—"Skilled tradespeople won't buy into the program"; "Skilled trades supervisors resist any change"—which were viewed as expressions of normal resistance to change.

In effect, the program consisted of indoctrinating management and the workforce in the benefits of conducting a pre-job review that encompassed how to complete the job effectively in a timely manner, as well as job hazard analysis and risk assessment. Eventually, management and skilled trades personnel agreed that information sessions would be held (which the safety professionals later called vital to their success).

At the beginning of those sessions, attendees received a discussion outline that presented the fundamentals of the proposed pre-job review system. After discussing the outline, attendees were divided into groups to plan actual maintenance jobs described in various scenarios. Figure 1 presents a comparable outline that is a composite of pre-job planning and safety analysis methods.

At this location, skilled trades supervisors became proponents of pre-job analysis and planning once they recognized that it made their jobs easier, improved productivity and reduced risks. As one safety professional involved says, "Our skilled trades supervisors who have been involved in the process have become real believers in it." A culture change had been achieved.

Some companies require contractors that perform work on their premises to submit written pre-job safety plans as part of the bid qualification process. In that respect, the construction industry is ahead of other business and industry categories. Figure 2 presents a pre-job plan and safety analysis prepared before work commenced on a construction project.

Conclusion

To a large extent, hazards and risks that present severe injury or fatality potential are identifiable. Preferably, these hazards/risks would be addressed in the design processes for facilities, equipment, operating systems, tooling, processes or products, and in the design of the work methods. Data on fatalities and serious injuries establishes that hazards and risks with severity potential are not always considered and reduced to a practical minimum in the design process, however. Therefore, it is not unusual to find such potential in facilities and operations.

Unfortunately, some safety practitioners continue to act on the premise that if efforts are concentrated on frequently occurring accidents, the potential for severe injury will also be addressed. That results in severe injury potential being overlooked, since the types of accidents that produce severe injuries or fatalities are rarely represented in the data pertaining to accidents which occur frequently. A sound case can be made that many accidents which result in severe injury or fatality are unique and singular events, yet safety management systems rarely specifically address severe injury potential. Thus, to properly address that potential, safety practitioners must undertake separate and distinct activities to identify hazards which present severe injury or damage potential, so that they can be given the priority consideration needed. ■

Hazards and risks that present severe injury should be addressed in the design processes for facilities, equipment, systems, tooling, processes or products.

References

EPA. "General Guidance for Risk Management Programs." 40 CFR Part 68, Chemical Accidental Release Prevention. Washington, DC: EPA, July 1998.

Grimaldi, J.V. and R.H. Simonds. *Safety Management.* 5th ed. Homewood, IL: Irwin Press, 1989.

"Guidelines on a Major Accident Prevention Policy and Safety Management System." As required by Council Directive 96/82/EC. Luxembourg: Office for Official Publications of the European Communities, 1998.

Hendrick, K. and L. Benner Jr. *Investigating Accidents With STEP.* New York: Marcel Dekker Inc., 1987.

Heinrich, H.W. *Industrial Accident Prevention: A Scientific Approach.* 1st ed. New York: McGraw-Hill, 1931.

International Labour Office (ILO). *Prevention of Major Accidents.* Geneva, Switzerland: International Occupational Safety and Health Information Center, ILO, 1993.

Johnson, W.G. *MORT Safety Assurance Systems.* New York: Marcel Dekker Inc., 1980.

Kriebel, D. "Occupational Injuries: Factors Associated with Frequency and Severity." *International Archives of Occupational and Environmental Health.* 50(1982): 209-218.

Main, B.W. "Risk Assessment for Maintenance Activities: Preventing Injuries Before They Happen." Ann Arbor, MI: Design Safety Engineering, 2001.

National Safety Council (NSC). *Accident Prevention Manual: Administration & Programs.* 12th ed. Itasca, IL: NSC, 2001.

Norman, D.A. *The Psychology of Everyday Things.* New York: Basic Books, 1998.

OSHA. "Process Safety Management of Highly Hazardous Chemicals." 29 CFR 1910.119. Washington, DC: U.S. Dept. of Labor, OSHA, 1992.

Petersen, D. *Safety Management.* 2nd ed. Des Plaines, IL: ASSE, 1998.

Tarrants, W.E., ed. *The Measurement of Safety Performance.* New York: Garland Publishing, 1980.

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