Establishing the Level of Danger

Key factor in personal injury and property damage lawsuits

By Robert J. Firenze

SAFETY ENGINEERS ARE OFTEN ASKED to help engineers design and implement safety measures to minimize injuries to people and damage to property. In addition, these same professionals may be asked by lawyers to help determine whether the factors that contributed to an injury are worthy of a lawsuit or to testify in court to explain the significance between the injury and its causal factors.

In the author's experience fulfilling these two functions, two situations became obvious:

1) Design engineers do not always fully assess the extent of threats to people and property and, consequently, do not engineer and implement measures that provide needed safety.

2) Lawyers often fail to understand what the engineer should have done to minimize the occurrence of the accident and its subsequent injuries.

This article introduces a formula and method designed to help the engineer be more effective in assessing the significance of threats to people and property as well as to help the attorney understand what the engineer did prior to the accident. This insight may prove valuable in accepting a case or building an argument in a lawsuit.

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Defining Danger

Throughout this article danger is used interchangeably as a threat of harm to people and/or damage to property (Brenner). This threat of harm is produced by three factors: 1) the hazard's inherent capability to cause harm; 2) the risk(s) or opportunity(s) that existed to enable the hazard to produce harm; and 3) the extent of impact that the resultant harm had on people and property. The words hazard, risk and exposure are often used inconsistently or as synonyms for safety. However, whether in engineering or in the courtroom, these terms must be defined precisely and be understood by all involved.

Before danger is considered in greater detail, it may be useful to first discuss safety. *Webster's Dictionary* boils it down to a few extremely valuable words: Safety is "the freedom from exposure to danger." Therefore, if safety is the target, the engineer must determine and assess the elements that produce it, then calculate the degree to which the danger compromised safety and is primarily responsible for the injury-producing accident.

Danger is the threat of harm to people and/or damage to property; serious injury or death to people or extensive damage to property is a potential outcome. Danger is the unreasonable or unacceptable combination of hazard(s)/risk(s) coupled with the failure to implement or use available safety measures. The engineer's primary objective must be to demonstrate the excessiveness of the danger that led to the accident which resulted in personal injury or property damage.

The engineer must also understand the two types of danger: unreasonable and unacceptable danger and reasonable or acceptable danger. On one end of the spectrum, danger is unreasonable and unacceptable if the outcome is serious injury, death and/or extensive property damage and reasonable accident prevention methods could have eliminated the threat. At the opposite end of the spectrum, a very high risk of injury or property damage can be acceptable if the potential injury or property damage is minimal or is justified by real-world operating conditions (e.g., military combat, fire evacuation and rescue operations).

Four questions associated with a preliminary assessment of danger are worth examining.

1) Why does the danger (threat) exist? Is it the manifestation of departing from a controlled situation or because the situation is inherently dangerous and, even with safety measures in place, always poses harm to people and property? Consider these two examples:

•Example 1: A worker is performing a cleaning task that involves diluting nitric acid with water. He is wearing protective eye goggles, but is working in a poorly illuminated and ventilated area. As he is working, the water contacts the acid and the resulting reaction causes it to spray on his face, causing severe acid burns. This scenario illustrates that the threat (danger) to the person being severely injured while working in close proximity to the acid is high.

•Example 2: A worker is performing the same cleaning task. In this case, he is wearing a full faceshield and clothing that is impervious to the acid. In addition, the area has adequate illumination and is properly ventilated. Through these measures the danger of an acid-caused injury is eliminated or at least minimized regardless of the continued use of the acid. In this case, one could successfully argue that the danger is low.

2) Is there possible utility of the danger? All dangers are not the same. For example, missiles with warheads present a significant threat, yet they have a utility and serve a purpose. On the other hand, the danger (threat) of exposing people to a carcinogen or an acid has no utility and serves no useful purpose.

3) Are users aware of the danger? This is directed to the quantity and completeness of warnings and other information supplied regarding the dangers anticipated under foreseeable conditions of use of the product or process. While a warning has some safety-related significance, it is never a substitute for sound engineering design and personal protective and safety measures that minimize or eliminate the threat. It is also important to note that many safety measures shift the burden of protection to the user. In Example 1, the person was inadequately protected.

4) Could the danger have been minimized or eliminated? Strategies such as using engineering controls, implementing safety measures and providing adequate supervision are examples of ways to reduce the threat to people and property.

Some danger is associated with many aspects of work or recreation and is a fundamental reality in some situations. The necessary conditions for danger are a combination of hazard and risk, and scientifically and economically feasible safety measures that could reduce or eliminate the constituent elements of hazard, risk or exposure to people and property. Finally, accidents are relatively rare events. The number of times this result of danger occurs, divided by the total number of times it could have, yet did not, occur, yields a very small percentage. To the untrained eye, these low values will likely be interpreted to mean acceptable threat to people and property.

One other point further complicates the assessment of danger and the elements that produce it. Specifically, danger may be comprised of one hazard and several risks, or several hazards and several risks. In Example 1, the worker is exposed to a single hazard presented by the acid while working under poor lighting and inadequate ventilation conditions.

In conclusion, the engineer and lawyer must contend with five challenges. They must:

1) identify the danger that produced the outcome;

2) demonstrate the unreasonable excessiveness of the danger;

3) identify the hazard(s) that when combined with risk produced the danger;

4) estimate risk;

5) identify specifications and variance(s) that are part of the causal chain leading to the accident and resultant injury.

Danger is the unreasonable or unacceptable combination of hazard(s)/risk(s) coupled with the failure to implement or use available safety measures. The engineer's primary objective must be to demonstrate the excessiveness of the danger that led to the accident which resulted in personal injury or property damage.

The Relevance of Standards

One of the first steps in assessing the danger associated with an accident is to determine whether standards and/or specifications existed prior to the accident and to what extent they relate to it. Safety-related standards are published by organizations such as American Society of Testing Materials, ANSI and Consumer Product Safety Commission. Specifications appear in documents such as manufacturers' equipment manuals, industry protocols and a company safety manual. Standards and specifications may be useful in establishing a benchmark of what should have existed before the accident; from here, it may be possible to determine whether departures (variances) had occurred.

Many standards are promulgated on the basis of consensus, not necessarily on the best possible solution. Consensus standards are those "produced by a body selected, organized and conducted in accordance with the procedural standards of due process. In standards-development practice, a consensus is achieved when substantial agreement is reached by concerned interests according to the judgment of a duly appointed review authority" (Cavanaugh).

The common industrial hardhat provides an example. In ANSI Z89.1, the recommended design of an approved hardhat includes a shell and a suspension system designed to protect a person's head in the potential gains. In any event, should a worker wearing an approved hardhat suffer a serious brain injury and it can be proved that the hardhat design, while necessary, was insufficient, the lawyer is often able to argue convincingly on the plaintiff's behalf.

Table 1

Hazard Severity

Category	Title	Weight	Description
I	Catastrophic	4	May cause death or extensive injury to people or loss of or extensive damage to high value property.
II	Critical	3	May cause severe injury, severe occupational illness or major property damage.
III	Marginal	2	May cause minor injury or minor occupational illness resulting in lost workday(s) and/or marginal property damage.
IV	Negligible	1	Probably will not affect a person's safety or health and will probably result in less than significant property damage.

Table 2

Property Damage Cost Estimates

Category	Title	Weight	Description
I	High Value	4	$199,000 to $1 million+
II	Major Value	3	$20,000 to $199,000
III	Marginal Value	2	$2,000 to $19,999
IV	Negligible Value	1	$500 to $1,999

event of impact by an object. This standard has existed since 1968 and hardhats designed according to this standard are found in most work environments. The question is whether a hardhat that meets this standard provides adequate protection against brain injury.

This depends on a person's point of view. If the objective is to protect the cranium, and the person is struck in the general area of the apex of the hardhat, then adequate protection may be afforded by existing head protection systems—although this protection affords lesser protection from some side impacts (angular acceleration). However, if the objective is to protect the brain instead of the cranium in head-impact situations, the approved head protection system may not be effective. Current research suggests that injury is intimately related to to the local response of the brain and not to the global input to the head (King, et al). It has also been shown that when a person is impacted by an object to the head, it is conceivable that the cranium may stay intact while the forces delivered to it may cause life-threatening blood clots on the brain; and that while the cranium and brain are unaffected by the impact, the forces delivered to the hardhat may be transmitted to the neck and spine, producing injuries at a later date (Lebow and Evans).

The cited research suggests that design alternatives may provide better protection against head impact. However, cost, ease of use, interference, comfort and other factors must be weighed against the

Avoiding the Trap

Many people mistakenly assume that compliance with a safety standard mitigated the degree of danger that existed at the time of the accident. The engineer must recognize that if complying with a safety standard does not eliminate or minimize a condition of danger, then the standard is irrelevant and other supporting information must be acquired to produce an acceptable result.

One must also understand that if a federal or state safety standard does not exist for a specific situation, those with the responsibility to provide a safe environment for people are not held harmless. The case of *Shannon v. General Motors Corp.* illustrates this (see pg. 35 for more details). At the time of the accident, no OSHA standard required hoisting hooks to be equipped with a safety latch. However, the condition of danger presented by a choker on the open-hook required the employer to take prudent action to safeguard the worker.

Standards are minimum requirements, not necessarily the best solutions for every situation. In many cases, an existing standard may not provide adequate control. In other cases, a standard does not exist to eliminate or minimize danger. That said, the requirements in standards should be considered as part of the overall assessment of the opportunity (risk) in a given accident.

The Element of Hazard

Although many definitions of hazard exist in both the business and lay-world, one is particularly useable in every instance: "any condition with the inherent capability to injure people or damage property." Most would agree that some products and conditions exist which because of their composition or configuration can cause harm. Thus, one can also conclude that no matter what interventions are made, the hazard's ability to produce harm is unaffected. For example, inherent in the molecular composition of nitric acid is its ability to damage human tissue upon contact; it will always possess this quality. To protect a person from the destructive forces of a hazard, measures may include strategies such as implementing engineering controls to prevent contact with the hazard or shielding the person with safety and protective devices.

Attorneys for the plaintiff and defendant may argue over the relevance and importance of a hazard in a given situation with different motives. The plaintiff's lawyer seeks to illustrate the worst-possible consequences that the hazard could produce, while the defense's lawyer tries to minimize the relevance and connection of the hazard to the injury or property damage.

Assessing Hazard Severity

The degree of a hazard's severity is determined by an assessment of the worst-possible (severe) consequences it could produce, defined by the degree of injury, illness or property damage that may ultimately occur (Tables 1 and 2).

The Element Risk

In the lay-world as well as in the field of law, risk is considered to be the nonquantifiable chance that an individual might be exposed to harm, injury or loss. This definition is a near paraphrase of that used in the field of law as well as safety. But the definition does not include an element of great interest—namely, the probability (in quantitative terms) that the design of a product or process will expose an individual using or working in it to harm.

With sufficient historical data, it may be possible to quantify the probability of risk. For example, the risk of a fatal maintenance-related accident involving a multipiece rim is lower than the chance of a fatal accident in many daily activities. It presents a one-in-one-million chance of occurrence—68 fatal accidents for 404,700,000 tire changes or approximately one maintenance-related fatal accident for every 5,951,000 rims serviced. The risk of a fatal accident from maintenance of multipiece rims is approximately one in every 300 billion miles of tire travel. Low probability numbers do not necessarily mean that these wheels are safe, yet a layperson may interpret a one in 300 billion risk as safe and not be concerned.

Therefore, while it would be extremely desirable to be able to quantify the probability of all risks, it cannot be done. With no alternative, risk is defined in qualitative terms, not in the quantitative terms engineers need to estimate the probability that an accident may occur (Ing). It should also be noted that the "opportunity" and "probability" concepts of risk can be used interchangeably provided that no claim of statistical reliability of probability is made that cannot be readily proven (Robinson).

Qualitative Assessment of Risk in the Military

The argument for using qualitative instead of quantitative assessments dates back many years. Early evidence of such assessment schemes appeared in MIL Standard 882, System Safety Program for Systems and Associated Subsystems and Equipment: Requirements for: (1969), which later became MIL Standard 882A (1979), 882B (1984), 882C (1993) and 882 D (2000). In the first MIL STD 882, the importance (level) of a hazard was based only on a qualitative measure of the hazard stated in relative terms—whether the hazard was believed to be catastrophic, critical, major or negligible. By the time this standard reached its third revision, hazard severity was still determined by a qualitative measure of the worst-credible mishap and the probability of the hazard was made by assigning a qualitative hazard probability number derived from analysis, research and evaluation of historical safety data.

Need for a Workable Definition of Risk

Therefore, it may be more practical to define risk as the opportunity for a hazard's harmful capability to act on humans or property. Risk is any condition that exposes humans and property to this harmful capability (Brenner). Thus, risk is the opportunity and is measured by the probability (number of times it is likely to occur). Risk(s), in conjunction with hazard(s), set up the probability (mathematical expression) of harm. In this context, the term probability is the likelihood that the event will occur, not the feasibility (theoretical happening) of that occurrence.

One definition of hazard is useable in every case: "any condition with the inherent capability to injure people or damage property." Most would agree that some products and conditions exist that because of their composition or configuration can cause harm. Thus, one can also conclude that no matter what interventions are made, the hazard's ability to produce harm is unaffected.

Probable Consequences Are Implicit in the Definition of Risk

Suppose a situation exists in which it is common practice to run internal combustion engines inside a vehicle maintenance shop without adequate local exhaust and general ventilation. The hazard is carbon monoxide gas produced by the internal combustion engine. Furthermore, the overall level of danger increases when the engines run, creating the opportunity for technicians inside the shop to breathe the deadly gas. This additional opportunity increases the probability that a harmful incident (injury or fatality) will occur. Thus, implicit in the concept of risk is the "opportunity and increased probability for harm" (Brenner). For the purpose of this discussion, risk is hereafter defined as "the probable opportunity (situation) that enables a hazard to injure people and damage property." It is measured by a qualitative estimate of the number of times it is likely to occur. Thus, in the earlier example, this estimate must be high—it is a constant occurrence.

Risk-Enhancing Factors

Many dangerous situations have a single hazard-increasing element (risk) plus several risk-enhancing factors (Blumenthal). For example, a technician in a time crunch to install a strut assembly on an aircraft using his index fingers to align the pin holes in the holes in the clevis casting and tapered end of a heavy strut. A hydraulic jack was used to raise and lower the strut assembly during the alignment process. During the alignment, the jack failed, causing the strut to fall while the technician had his fingers in the holes; both index fingers had to be amputated. Analysis of this example illustrates three risk-enhancing factors. The technician: 1) used his fingers instead of a specified alignment tool for the job; 2) could not see what he was doing as he was forced to work in the "blind"; and 3) was under pressure to complete the job.

If one agrees that the hazard in this case was the sharp edges of the castings, then the risk(s) (opportunities most closely associated with danger and accident) are: 1) the technician was using both fingers to align the holes; and 2) the jack failed under the load. Further inquiry revealed that an alignment tool was not provided and that using fingers to align the pin holes in the clevis and strut was a common practice even though a specification that called for the use of a special alignment tool had been issued. No jack testing and maintenance protocol were in place either.

Table 3
Risk Probability

Category	Weight	Description
Frequent	1.0	Constantly occurs
Likely	0.75	High frequency of occurrence
Occasional	0.25	Medium frequency of occurrence
Seldom/Unlikely	0.05	Low frequency of occurrence or will not occur

Table 4
Exposure Level

People Exposed	Property Exposed	Weight
10 or more people exposed	High exposure	4 3
5 to 9 people exposed	Major exposure	2
1 to 4 people exposed	Marginal exposure	1
0 people exposed	Negligible exposure	

Exposure is a two-part measure. For example, even if no people are exposed but high-value property is exposed, the exposure level is still rated as 4. Similarly, the presence of medium-value property where six people are exposed would raise the exposure level from level 2 to level 3. Other similar operations going on at the same time in other parts of an organization or in the community at large may influence the weight given to exposure.

Common Traits among the Factors

Using index fingers to obtain pin alignment may have been perceived as a perfectly safe work practice although it was obviously a risk element in the accident. Similarly, failure to use the specified alignment tool, albeit a highly unsafe practice, nonetheless was not a foreseeable condition of use (it was not provided) and had not produced any prior mishaps. This example also illustrates that no single risk factor comprised the overall risk. However, each of the listed factors had a part in the ultimate outcome—namely, the worker's fingertips being sheared off by the falling strut. Although other factors enter the analysis, one could justifiably treat the absence of the alignment tool as the primary risk (opportunity) associated with the accident, with the other risk-enhancing conditions being of secondary importance. What makes one risk factor stand out above others varies from case-to-case, but arriving at that primary risk factor(s) is critical in building a meaningful case.

Confusing Human Error with Acceptable Risk

In the previous example, one could argue that the worker was at fault—he put his fingers in danger by committing an unsafe act. The counter argument is that the system (process) is at fault. A counter argument would deservingly be system-induced human error (Ing). Job requirements exceeded the person's ability to protect himself. The process, as designed and operated, draws the worker into an unsafe situation over which s/he has little control. In this example, there was no alignment tool; the practice had been in use for so long that it had become standard procedure—and supervision had, knowingly or not, endorsed it.

Confusing Hazard & Risk

The Air Force, in Policy Directive 90-901 and Air Force Pamphlet 90-2, creatively explains risk assessment. It blends hazard (the capability to cause harm) with risk (the opportunity presented that enables the hazard to actually cause harm) to arrive at this statement: "When we know the various impacts a hazard may have on our mission and an estimate of how likely it is to occur, we can now call the hazard a risk." This is an excellent example of how the terms hazard and risk are considered synonymous. Such a definition is generally not acceptable in engineering or in the courtroom where terms must be precise and unambiguous.

A Formula for Estimating Risk Probability

In addition to estimating a hazard's severity, one must determine and weight the probability of risk. This is accomplished by first making a qualitative estimate of the risk based on experience, historical information or through analysis. Table 3 illustrates

Figure 1

The Danger Value

Exposure Level 1

Risk Probability	Hazard Severity 1	2	3	4
1.0	6.250	12.500	18.750	25.00
0.75	4.688	9.375	14.063	18.750
0.25	1.563	3.125	4.688	6.250
0.05	0.313	0.625	0.938	1.250

Exposure Level 2

Risk Probability	Hazard Severity 1	2	3	4
1.0	12.50	25.00	37.50	50.00
0.75	9.38	18.75	28.13	37.50
0.25	3.13	6.25	9.38	12.50
0.05	0.63	1.25	1.88	2.50

Exposure Level 3

Risk Probability	Hazard Severity 1	2	3	4
1.0	18.75	37.50	56.25	75.00
0.75	14.06	28.13	42.19	56.25
0.25	4.69	9.38	14.06	18.75
0.05	0.94	1.88	2.81	3.75

Exposure Level 4

Risk Probability	Hazard Severity 1	2	3	4
1.0	25.00	50.00	75.00	100.00
0.75	18.75	37.50	56.25	75.00
0.25	6.25	12.50	18.75	25.00
0.05	1.25	2.50	3.75	5.00

For example: For a situation with an exposure level (E) of 4, a hazard severity level (HS) of 3 and a risk probability (RP) of 0.75, the danger value (DV) will be 56.25.

categories of risk probability—an expression of how often the risk (opportunity) occurs. These estimates are used later in calculating the level of danger. Despite the problems inherent in estimating and interpreting numerical percentages and probabilities, using an estimate of risk is unavoidable. Extreme care must be exercised in all probability usages whether in the context of hazard, risk, danger or foreseeability.

Lawyers on either side may also argue over the relevance and importance of risk in a given situation. The plaintiff's lawyer seeks to illustrate the high frequency (occurrence) of the risk and its relevance to the injury or property damage. The defense lawyer tries to minimize the existence of the risk. How effectively each argues his/her position will be critical to making a convincing argument for the presence of danger at the time of the accident.

The Element of Exposure

Without considering the extent of the impact (exposure) that the danger has on people and property, one cannot obtain an accurate estimate of the overall relevance of danger. This is not easy but it can be accomplished as long as a reasonable scale is used and consistently applied.

In addition to estimating the severity of the hazard and the probability of risk, one must assess and weight the level of exposure (impact) on people and property. This is accomplished by estimating how many people and/or what value property (Tables 1 and 2) are likely to be exposed to the danger on a regular basis, then weighting these estimates using the values in Table 4.

The Probability of Danger

It would be wonderful if the importance of danger could be quantified in every instance. Since this is not feasible, however, estimates of the degree to which people are injured or property is damaged are developed based on experience, historical information or through analysis, then by assigning a predetermined weight (e.g., 4 high and 1 low) that will be used later in the calculation of the level of danger. As with injury estimates made in Table 1, property damage estimates must also be made when required. Table 2 illustrates a range of costs that correlate with the value of the property.

Computing the Danger Value & Danger Index

Using statistical decision theory, Professor Donald Robinson, a statistician and psychologist now retired from Indiana University, determined the relative magnitude of a danger level derived from a multiplicative relationship among the factors of hazard, risk and exposure (Robinson). The goal was to have the danger level increase with increasing values of risk probability, hazard severity and exposure. These multiplicative relationships were used to construct the tables for estimating the danger level (Figure 1).

The Objective: The Danger Value

The objective is to arrive at a numerical value that establishes the degree of danger—not the degree of hazard or the degree of risk—but the relationship among hazard, risk and exposure. The components of the danger value (DV) are hazard severity (HS), risk probability (RP) and exposure (E). The formula for DV is:

$$DV = 100 \times \frac{(HS)(RP)(E)}{16}$$

DV is multiplied by 100 to round out the numbers. As this formula shows, DV weighs hazard severity, risk probability, and the number of people or value to property exposed to the danger. It may be used by the engineer to establish the priority for action in eliminating or minimizing danger and accidents. It may also be used by the lawyer to establish the existence and importance of danger at the time of the injury- or property-damage-producing accident.

Table 5

Danger Index

DI Action Priority	Danger Value
4 = Highest importance/Immediate action priority	75-100
3 = Considerable importance/High action priority	50-74
2 = Moderate importance/Moderate action priority	25-49
1 = Relatively low importance/low action priority	0-24

Calculating DV

•Step 1. Determine the weighted severity of the hazard (HS). Use Table 1 to estimate the weighted consequences (severity) of the hazard.

•Step 2. Calculate the weighted probability of the risk (RP). Use Table 2 to estimate the frequency or how often the risk (opportunity) occurs.

•Step 3. Calculate the weighted extent of exposure (E). Use Table 3 to estimate the extent of impact the hazard has on people and property.

•Step 4. Determine the DV. It is the product of HS, RP and E divided by the constant 16. To arrive at DV:

1) Locate the quadrant in Figure 1 that matches the calculation of exposure.

2) Find the estimate of HS in the quadrant.

3) Find the estimate of RP in the quadrant.

4) Where the two calculations for HS and RP intersect is DV.

The Danger Index

The danger index (Table 5) provides the engineer with a way to prioritize action based on a rational assessment of the importance of danger in a given situation (Firenze). It is also helps the lawyer show that the existence of an unacceptable level of danger existed prior to the injury- or damage-producing accident.

Calculating the Danger Index (DI)

DV corresponds with four DI priority numbers. Priority number 4 (DV 75-100) is the highest importance and requires immediate action. Priority number 1 (DV 0-24) is relatively low in importance and action priority. A DV of 56.25 is considered to be priority number 3, meaning it is of considerable importance and a high action priority.

Dealing with Multiple Hazards & Risks in the Same Situation or Accident

In situations where multiple hazards and risks are associated with a single accident, each hazard/risk relationship and its corresponding exposure should be assessed independently to identify its DV and DI. Table 6 illustrates three hazard, risk and exposure combinations that produce three different DVs and DI action items.

Examples: Establishing The Level of Danger

In *Dillenbeck v. Bachtold Brothers Inc.*, the plaintiff rented an all-purpose mower from a equipment rental company to clear property. During the cutting process on a damp and sloping terrain, the unguarded blade on the machine, protruding 4.5 inches beyond the cowling, became caught in the terrain. The resultant force pulled Dillenback to the ground alongside the mower's protruding cutting blade. He sustained severe lacerations and his right hand was amputated.

Examination of the mower indicated that in addition to the protruding unguarded blade the drive lever was equipped with locking linkage that allows the engine to run until the operator releases it. This mechanism violated ANSI B 71.1, which specified that a deadman control be used to automatically interrupt power to a drive when the operator's actuating force is removed. In this case, the hazard was the sharp protruding cutting blade. It had the inherent ability to injure people and damage property. It was weighted as a 3 (critical).

Three risk-enhancing events (opportunities) were associated with this accident as well. First, the blade was unguarded, allowing it to come into contact with a person's body parts. Second, the unit had no deadman control so power was not interrupted to the blade when the operator's actuating force was removed. Third, the machine was used on uneven, damp terrain.

The first risk (opportunity) presented by the unguarded blade was considered to be of high frequency, as it constantly occurred. It received a weight of 1.0. The second risk was presented by the omission of a deadman control. It was also considered to be of high frequency and received a weight of 1.0.

In considering exposure, the fact that the machine was rented and that in addition to the plaintiff any number of other people who rented the machine had been and would in the future be in danger, exposure was rated as 4—high exposure.

Therefore, using the formula to determine DV: HS is 4, RP is 1.0, RP (second risk) is 1.0 and E is 4.

$$DV = 100 \times \frac{(HS\ 4)(RP\ 1.0)(E\ 4)}{16}$$

Starting with exposure level 4 (Figure 1), the intersection where HS of 4 intersects with an RP of 1.0, the product is 100.00, the highest level of danger. In this example, the danger existed because of the

Table 6
Hazard/Risk/Exposure Combinations

Hazard	Risk(s)	Exposure	DV	DI	Action
Catastrophic (4)	A (1.0)	3	75.00	4	High priority
Critical (3)	B (0.75)	2	28.13	2	Moderate priority
Catastrophic (4)	C (0.25	3	18.75	1	Low Priority

absence of a guard to protect the operator from the blade, and the inability to comply with an existing safety standard that called for a deadman control on this type of machine.

In *Shannon v General Motors Corp.*, the plaintiff was cleaning sand that had become caked on the inside of a large steel hopper in preparation for demolition. He was suspended in a boatswain chair rigged with a 1/2-inch choker and a 3/4-inch shackle hooked to a traveling snatch block with an open hook. The rigging line was 1/2-inch wire rope that a traveling snatch block rode on. The traveling block was attached to and guided by another employee with a 3/4-inch fiber hand rope. As the plaintiff was lowered into the hopper, the rigging on his boatswain chair became disengaged from the hook on the traveling snatch block. He fell 60 feet to the bottom of the hopper after first hitting an intermediate beam located in the hopper's midsection. The injured was not wearing a safety belt or lifeline. The hook on the snatch block was the open type with no safety latch.

In this case, the hazard was the 60-foot fall to the bottom of the hopper. It was determined that this hazard was critical as it had the inherent capability to seriously injure or kill a person. It was weighted as a 4 (catastrophic).

Two risk-enhancing events were associated with this accident as well. The first was using a hook without a safety latch; it is considered to be of high frequency as it was common practice for the contractor to use open hooks in demolition operations. Thus, this risk received a weight of 1.0, as it constantly occurs. It should be noted that when this accident occurred it was common practice in the construction industry to use safety hooks although OSHA standards did not require it.

The second risk enhancer was performing the task while not wearing a life belt and safety line. This was considered to be a high frequency occurrence and received a weight of 1.0. In considering exposure, as approximately six workers were present on the jobsite (any of whom could have been assigned this task) exposure was rated as a 3 (major exposure). Again, using the formula to determine DV: HS is 4; RP (first risk) is 1.0; RP (second risk) is 1.0; and E is 3.

$$\mathbf{DV = 100 \times \frac{(HS\ 4)(RP\ 1.0)(E\ 4)}{16}}$$

Referring to Figure 1, starting with exposure level 3, the intersection where HS weighted 4 intersects with RP of 1.0, the product is 75.00, or the highest level of danger. In this instance, the danger existed because no safety latch was used on the hook and because the worker did not wear a safety belt with lanyard. Both safety measures were necessary actions and would have been sufficient to minimize danger and avoid the accident.

Conclusion

The discussion of the elements of danger, and the formula and method presented do not suggest that this is the only way to arrive at a defensible arguments to support engineering decisions or lawsuits. The intent was to provide an orderly approach which forces both the engineer and lawyer to address key questions about the elements of danger so that they may be more confident that their conclusions are both logical and communicable to those who will make decisions that affect the safety of individuals or the compensation for the injuries they have sustained. ■

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