Root-Causal Factors

Uncovering the Hows & Whys of Incidents

By Fred A. Manuele

This article began after reading some thought-provoking comments about incident causation by authors Erik Hollnagel and Sidney Dekker. Hollnagel is the author of *Barriers and Accident Prevention* (2004), and Dekker wrote *The Field Guide to Understanding Human Error* (2006). OSH professionals should read the writings of both. Consider some of their commentary:

1) One can describe and understand an incident in several ways, and the cause-effect assumption is perhaps the least attractive option (Hollnagel, p. 26).

2) The tendency to look for causes rather than explanations is often reinforced by the methods used for incident analysis. The most obvious example of that is the principle of root-cause analysis (Hollnagel, p. 26).

3) Root cause is a meaningless concept (Hollnagel, p. 28).

4) There is no root cause (Dekker, p. 77).

5) What you call *root cause* is simply the place where you stop looking any further (Dekker, p. 77).

6) Where you look for causes depends on how you believe incidents happen. Whether you know it or not, you apply an accident model to your analysis and understanding of failure (Dekker, p. 81).

The positions Hollnagel and Dekker take are educational and promote introspection. Safety professionals should analyze these positions for their possible effects on the practice of safety. The excerpts in this article are intentionally presented like book reviews. This was done to illustrate the breadth of what these noteworthy authors have written about how incidents happen, incident causes, root causes and incident analysis.

In addition to reviewing and commenting on statements made by Hollnagel and Dekker, this article presents a concept that OSH professionals can practicably apply to determine root-causal factors. Identifying incident causal/contributing factors has long been a basic element in safety management systems. Simply stated, the purpose of an incident investigation is to learn from history and to make improvements to overcome the management system deficiencies noted in investigation reports.

IN BRIEF
- **Identifying incident causal/contributing factors has long been a basic element in safety management systems.**
- **Simply stated, the purpose of an incident investigation is to learn from history and to make improvements to overcome the management system deficiencies noted in investigation reports.**
- **This article presents a concept for determining root-cause factors that OSH professionals can practicably apply.**

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Hollnagel on Causation

Hollnagel's (2004) first two chapters, which span 58 pages, are titled "Accidents and Causes" and "Thinking About Accidents." He says that when investigating incidents, applying a cause-and-effect approach is the least attractive of all options. His premise is that causal/contributing factors do not occur sequentially in complex events (p. 26); for incidents that are not complex, a cause-and-effect method may be sufficient. Thus, a safety practitioner could determine its applicability by assessing the simplicity or complexity of a given organization's hazard/risk environment.

Hollnagel (2004) implies that investigators should seek the hows and whys of incidents, expressed in narrative descriptions, rather than seeking causes. He pleads for an understanding of the difference between explanations of the hows and whys an incident occurs and seeking causes (p. 26). He is particularly opposed to seeking root-causal factors (p. 26). However, this reasoning is difficult to follow because if an incident's hows and whys are determined, they are more than likely the causal factors.

Hollnagel (2004) recommends using prescribed causal factor models during an incident investigation, but says that because of their structure and content these models may interfere with or limit the process of determining the how and why of an event. That is an acceptable premise. Hollnagel says root-cause analysis is an example of a less-than-adequate incident investigation method, calling the concept deceptive. In Hollnagel's view, the method's name implies that the product of an investigation will be *the* root cause (p. 27). It is exceptionally important to note that Hollnagel refers to root-cause analysis in the singular. When he describes the root-causal concept as meaningless, he refers to attempts to find the one and only root cause of a problem (p. 28). Look for more about singularity later in this article.

Hollnagel cites philosophers (e.g., Nietzche, p. 25; Hume, p. 31) and what they have written about how difficult it is to determine the reality of causes. Generally, these philosophers' stance on cause is that there can be no uncaused cause; everything that exists has causes for its existence; and no matter how deeply one delves to identify causes, reasons will emerge for the existence of the identified causes and, thus, the attempt will be never ending.

Therefore, if an investigation stops because investigators become comfortable with their causal factor determinations, philosophers would argue that inquiry could continue. So, assume that as an investigation proceeds, management systems deficiencies are identified. While desirable to identify the reasons for their existence (e.g., senior management decisions), doing so when the investigations are performed by internal personnel would be an exception. Practicably, the investigation process stops when those involved conclude that their inquiry has reached its cultural and organizational limits.

Although Hollnagel (2004) repeats his view that it is difficult to define what a cause is, he offers the following plausible definition: "A cause can be defined as the identification, after the fact, of a limited set of aspects of the situation that are seen as the necessary and sufficient conditions for the observed effect(s) to have occurred" (p. 34).

This definition is consistent with applied and practical incident investigation processes, and it is one that safety professionals can confidently support. Hollnagel (2004) acknowledges that identifying incident causes is instructive and valuable in determining corrective actions (p. 32).

Hollnagel (2004) ends his first chapter by stating that determining cause is a "relative and pragmatic" venture, but that doing so is not "scientific." This is another logical premise. Some decisions made during an incident investigation result from what people say and, thereby, may be subjective and not necessarily reflective of good science. Nevertheless, in support of determining the correct causal factors, Hollnagel (2004) says, "The value of finding the correct cause or explanation is that it becomes possible to do something constructively to prevent future accidents" (p. 35).

As noted, the purpose of an incident investigation is to learn from history and to make improvements to overcome any management system deficiencies identified. That closely fits what Hollnagel says about the value of finding correct causes or explanations.

The positions Hollnagel and Dekker take are educational and promote introspection. Safety professionals should analyze these positions for their possible effects on the practice of safety.

Dekker on Causation

Dekker's (2006) *The Field Guide to Understanding Human Error* is particularly thought provoking because of the positions he takes on human error and how those views relate to his comments on incident investigation. Consider these excerpts.

> •Human error is not a cause of failure. Human error is the effect, or symptom, of deeper trouble. Human error is systematically connected to features of people's tools, tasks and operating systems. Human error is not the conclusion of an investigation. It is the starting point. (p. 15)
>
> •Sources of error are structural, not personal. If you want to understand human error, you have to dig into the system in which people work. (p. 17)
>
> •Error has its roots in the system surrounding it; connecting systematically to mechanical, programmed, paper-based, procedural, organizational and other aspects to such an extent that the contributions from system and human error begin to blur. (p. 74)
>
> •The view that accidents really are the result of long-standing deficiencies that finally get activated has turned people's attention to upstream factors, away from frontline operator "errors." The aim is to find out how those "errors" too, are a systematic product of managerial actions and organizational conditions. (p. 88)

Dekker's (2006) ninth chapter is titled "Cause Is Something You Construct." Some of his views mirror those expressed by Hollnagel (2004). For example, Dekker (2006) writes, "The reality is that there is no such thing as the cause, or primary cause or root cause. Cause is something we construct, not find. And how we construct depends on the accident model we believe in" (p. 73).

Note that the wording is singular as is Hollnagel's (2004) text. Dekker (2006) makes it clear that he is opposed to seeking a singular cause or singular root cause when investigating incidents.

Leveson (2011) also questions the concept of root cause. She implores incident investigators to use an incident model that promotes a "broad view" of an occurrence.

> An accident model should encourage a broad view of accident mechanisms that expands the investigation beyond the proximate events. A nar-

> row focus on operator actions, physical component failures, and technology may lead to ignoring some of the most important factors in terms of preventing future accidents. The whole concept of "root cause" needs to be reconsidered. (p. 33)

In a sense, Leveson (2011) supports the views expressed by Hollnagel (2004) and Dekker (2006) when she says that debating whether one causal factor is the root-causal factor among other causal factors wastes time and can be nonproductive (p. 56).

Dekker (2006) asserts that incident investigators do not find causes, but rather surmises that they construct them. That is, what an investigator identifies as causes is influenced by his/her assumptions about how incidents occur (p. 73).

This latter point, that causal factor determination is influenced by the investigator's beliefs about how incidents occur, is an important truism that should prompt extensive introspection and self-analysis by safety practitioners. For example, suppose an investigator believes that unsafe acts of workers are the principal causes of occupational incidents. That belief would have a significant effect as that investigator participates in determining causal factors.

Now assume that safety practitioners have taught management that unsafe acts are the principal causes of occupational incidents (which has occurred). Management personnel would then have the same understanding of how incidents occur and the investigation system would be grossly inadequate.

Synonyms for construct are *build, make, fabricate* and *create.* Dekker's (2006) statement is a reflection of his overall position that investigators do not in reality discover what causes incidents. In the author's experience, the determination of causal factors is often dismally shallow and is neither found nor created. Unfortunately, in a huge proportion of investigations, the causal factor determination stops with identifying an employee's unsafe act.

Again, the writings of Hollnagel (2004) and Dekker (2006) are substantially similar. Dekker writes:

> There is no "root" cause. What you call "root cause" is simply the place where you stop looking any further. You see that factor as necessary for the mishap to happen. Nothing else would have needed to go wrong; otherwise you would also have to label those things as "causes." (p. 77)

Dekker (2006) implies that an investigation system is deficient if it requires the identification of a single root cause. Dekker and Hollnagel (2004) also agree that there is no such a thing as *a* root cause and that it is folly to try to establish *a* root cause for an occurrence that has several contributing causes. The author's research supports this. "Many incidents resulting in serious injury are unique and singular events, having multiple and complex causal factors that may have organizational, technical, operating systems or cultural origins" (Manuele, 2014a, p. 62).

Dekker (2006) says that it would be better if investigators wrote about "explanations rather than causes" (p. 78). Note the term *explanations.* It appears several times in Hollnagel's (2004) book.

Like Hollnagel (2004), Dekker (2006) recognizes that some organizations require investigators to identify root-causal factors when their process is complete. His recommendation on what to do when such requirements exist is comparable to Hollnagel's as well. Dekker suggests that the investigator write a narrative, an explanation of the incident's how and why, that includes the issues and events that the investigator believes to be important, with designations of probable causes being subordinate (p. 78). As noted, the author believes that the how and why of an incident are likely the causal factors.

Hollnagel & Dekker on Incident Models

Hollnagel (2004) writes extensively about the need for an organization to select an incident model to serve as a base for incident investigation, communication and corrective action. Dekker's (2006) comments are not extensive, but they mirror Hollnagel's (2004) thoughts on three types of models.

Sequential Models

Sequential models view incidents as a result of a sequence of events that occur in a specific order. Heinrich's domino sequence was the first such model. Like many others, Hollnagel (2004) observes that sequential models are inadequate when incidents result from multiple causal factors that may contribute to an incident in parallel rather than sequentially (p. 47). He also continues to be nonsupportive of seeking a root cause (p. 51).

In discussing these models, Hollnagel (2004) comments further on the possible deterrent effects of applying the "stop rule" to determine when an investigation is complete. International standard IEC 62740:2015, Root Cause Analysis, includes a reference about the stop rule: "The 'stopping rule' is the point at which action can be defined or additional proof of cause is no longer necessary for the purpose of the analysis" (IEC, 2015, p. 15).

Hollnagel raises a valid point. Investigations typically stop too soon, thereby avoiding recognition of the management systems deficiencies that could be important among the causal factors. However, even if an investigation meets the stop rule requirements of the international standard, it is likely that certain philosophers (and Hollnagel and Dekker) would find the causal factor determination insufficient, believing that no matter where the investigation stops, it could have gone further.

Epidemiological Models

An epidemiological model would show an incident as deriving from a blend of causal factors, some active and others built up over time and existing in combination at the time the incident occurred. Hollnagel (2004) says that an epidemiological model considers performance deviations; deviations from safe practice; environmental conditions (technical and social aspects); the absence or ineffectiveness of preventive barriers; and latent hazardous conditions or practices that have accumulated over time (p. 54).

Systems Models

Application of a systems model requires one to consider individual systems as interrelated and inseparable parts of a whole. Hollnagel (2004) recognizes the value of a form of linear plotting (perhaps several linear plottings such as for a fishbone diagram) that may be causally related (p. 59). He writes, "Events can still be ordered post hoc either temporally or in terms of causal relations. But in the systemic model each event may be preceded by several events (temporally or causally), as well as be followed by several events" (p. 59).

Hollnagel (2006) recommends the use of a systems model (as does the author). Applying a systems model requires macro thinking rather than micro thinking. Using micro thinking, one would, for example, hold that unsafe acts are the principal causal factors for occupational incidents and stop an investigation once a worker's unsafe act is identified. Taking a macro view to determine causal factors requires thinking large about systems as integral and inseparable parts of a whole and their interrelationships. It also requires seeking management systems deficiencies, some of which could derive from an organization's cultural, technical and social aspects.

Hollnagel's (2004) fifth chapter, "A Systemic Accident Model," includes a depiction of his functional resonance as a systemic accident model (FRAM) (Hollnagel & Goteman, 2015, p. 171). FRAM is based on four principles: 1) the equivalence of failures and successes; 2) the central role of approximate adjustments; 3) the reality of emergence; and 4) functional resonance as a complement to causality. Hollnagel's thinking is new and interesting, yet because of the model's complexity, some safety practitioners will find it difficult to accept. In organizations with deeply embedded investigation systems, obtaining acceptance of FRAM will require a concentrated, multiyear effort to achieve the culture change necessary.

Dekker's (2006) 10th chapter is titled "What Is Your Accident Model?" He recognizes that a model helps one determine what is to be sought, yet he also says that a model may be restraining. He extends previous statements about how a person's understanding and beliefs about how incidents happen influences the thoroughness of an investigation. His observation has substantial weight and safety professionals should seriously consider it.

> Where you look for causes depends on how you believe accidents happen. Whether you know it or not, you apply an accident model to your analysis and understanding of failure. An accident model is a mutually agreed, and often unspoken, understanding of how accidents occur. (p. 81)

Dekker (2006) uses the same three model groups as Hollnagel (sequential, epidemiological, systems), and his comments on these models mirror Hollnagel's. Dekker also favors the use of systemic models. One can make a convincing case that root-causal factors (plural) can be most effectively identified by focusing on the whole of the sociotechnical aspects of operations as an interacting system (Manuele, 2014a, Chapter 5).

How many incident models currently exist? Safety Institute of Australia (2012) issued a document that highlights 32 such models. This document is available as a free download (**http://bit.ly/1XluQPI**).

Comments on Root Causes & Causal Factors

Entering the phrase "root causes of accidents" into a search engine will return an abundance of resources. Let's focus on selections from two publications.

Petersen (1998) comments on the concept of multiple causation and how an investigation into root causes should identify shortcomings in management systems. Note that Petersen writes in the plural.

> Multiple causation asks what are some of the contributing factors surrounding an incident? If we deal only at the symptomatic level, we end up removing symptoms but allowing root causes to remain to cause another accident or some other type of operational error.
>
> Root causes often relate to the management system. They may be due to management's policies and procedures, supervision and its effectiveness, or training. Root causes are those which would effect permanent results when corrected. They are those weaknesses which not only affect the single accident being investigated, but also might affect many other future accidents and operational problems. (p. 11)

Center for Chemical Process Safety (CCPS, 2003) publishes guidelines for investigating chemical process incidents, which include information on structured approaches to determining root causes. CCPS's definition of *root cause* begins in the singular, then recognizes that incidents usually have more than one root cause. "Root cause: A fundamental, underlying, system-related reason why an accident occurred that identifies a correctable failure(s) in management systems. There is typically more than one root cause for every process safety incident" (p. 179).

This definition is particularly noteworthy. It states that investigators are to seek "system-related reason(s)" and "failure(s) in management systems." Great emphasis must be given to examining the operating system that management creates. Reason (1990) appeals for recognition of the significance of system defects when discussing latent errors and system disasters. As they participate in or give counsel on incident investigation, safety professionals should seriously consider Reason's insight:

> Rather than being the main instigators of an accident, operators tend to be the inheritors of system defects created by poor design, incorrect installation, faulty maintenance and bad management decisions. Their part is usually that of adding the final garnish to a lethal brew whose ingredients have already been long in the cooking. (p. 173)

An International Standard

As noted, an international standard exists for root-cause analysis (RCA). Consider this abstract about the standard (IEC, 2015):

Determination of causal factors is often dismally shallow and the process often stops with identifying an employee's unsafe act.

> IEC 62740:2015 describes the basic principles of root-cause analysis (RCA) and specifies the steps that a process for RCA should include. This standard identifies a number of attributes for RCA techniques which assist with the selection of an appropriate technique. It describes each RCA technique and its relative strengths and weaknesses.
>
> RCA is used to analyze the root causes of focus events with both positive and negative outcomes, but it is most commonly used for the analysis of failures and incidents. Causes for such events can be varied in nature, including design processes and techniques, organizational characteristics, human aspects and external events.
>
> RCA can be used for investigating the causes of nonconformances in quality (and other) management systems as well as for failure analysis, for example in maintenance or equipment testing. RCA is used to analyze focus events that have occurred, therefore this standard only covers a posteriori analyses.
>
> The intent of this standard is to describe a process for performing RCA and to explain the techniques for identifying root causes. These techniques are not designed to assign responsibility or liability, which is outside the scope of this standard.

Given how standards-development committees work, it is understandable that the number of definitions for causal factors listed in the standard's definition category is excessive. They are repetitive and overlap, and use of all of them in an investigation system would promote valueless discussion and inefficiency. Nevertheless, all are listed here. Note that the definition given for *root cause* is in the singular but that the explanation transitions into the plural.

> •**Cause:** Circumstance or set of circumstances that leads to failure or success.
>
> •**Causal factor:** Condition, action, event or state that was necessary or contributed to the occurrence of the focus event.
>
> •**Contributory factor:** Condition, action, event or state regarded as secondary, according to the occurrence of the focus event.
>
> •**Focus event:** Event that is to be explained causally.
>
> •**Root cause:** Causal factor with no predecessor that is relevant for the purpose of the analysis.
>
> 1) A focus event normally has more than one root cause.
>
> 2) In some languages, the term *root cause* refers to the combination of causal factors that have no causal predecessor (a cut set of causal factors).
>
> •**Root-cause analysis:** Systematic process for identifying the causes of a focus event.
>
> •**Stopping rule:** Reasoned and explicit means for determining when a causal factor is defined as being a root cause. (p. 9)

This standard was reaffirmed in 2015. Its existence indicates that RCA is alive and well in many places around the world.

The Five-Why Problem-Solving Technique

Some consider the five-why problem-solving technique to be overly simplistic. However, research has revealed that the quality of causal factor determination as shown in incident investigation reports is often poor, even in large organizations (Manuele, 2014b). Thus, because of the observed status quo and what can be practicably attained, the author strongly recommends the five-why system as an initial undertaking to improve incident investigation quality.

The five-why system is easy to learn and apply to improve incident investigation quality. Case in point: One large company determined that if the five-why system were promoted and the company were able to give itself a B+ grade on investigation quality in 2 years, the company would have taken huge steps forward.

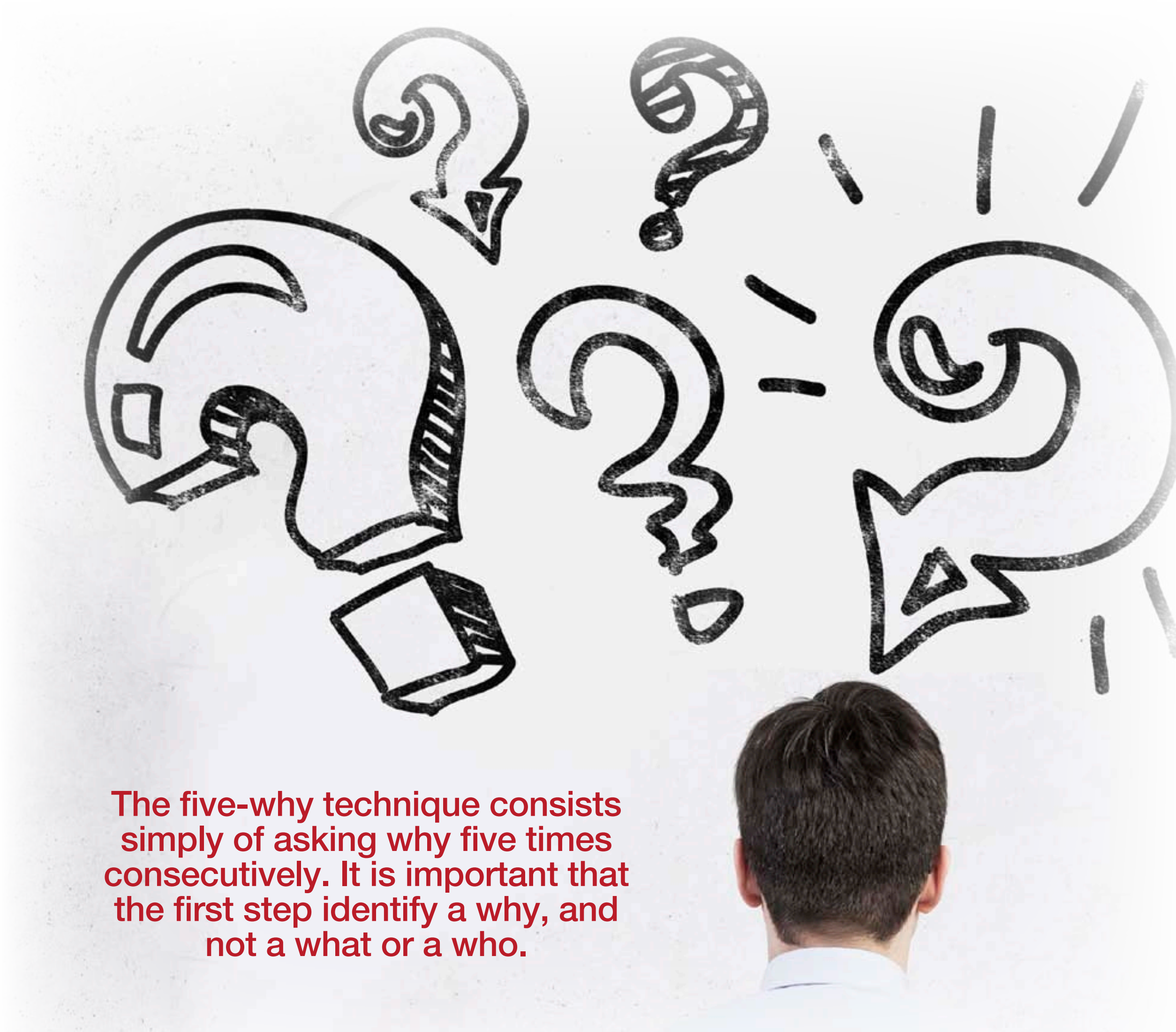
The technique consists simply of asking why five times consecutively. It is important that the first step identify a why, and not a what or a who. Sometimes, asking why only four times is sufficient. Occasionally, the process requires six or seven inquiries. Furthermore, in some situations, interjecting an occasional what or a how may move the inquiry forward. Occasionally, applying the technique to interrelated systems identifies actions that several operational entities should take to resolve a problem.

Safety professionals should select the categories of injuries or losses for which they would propose the use of the five-why system. Because of the time and expense involved and the limited benefits to be obtained, the system should not be used for minor incidents such as a paper cut or a scratch from an improperly set staple. However, it can produce beneficial results when applied to major incidents.

What is a major incident? Following is a composite list of the major incident categories established in various guidelines. Safety professionals can select from or add to this list as they develop a definition suitable to the organizations to which they give counsel.

- OSHA-reportable incident;
- hospitalization of an employee for more than 3 days;
- incident resulting in injury to three or more employees;
- a fatality;
- incident that did not result in harm or damage, but could have had serious consequences under other circumstances;
- incident resulting in property damage in excess of $10,000;
- product loss valued in excess of $10,000;
- environmental incident that was reported to a governmental authority;
- incident that required building or job site evacuation;
- incident that required emergency shutdown of operations;
- incident that could generate public interest;
- extraordinary or unusual incident creating a crisis or significant emergency;
- incident that will provide a lesson learned for other locations.

When using this technique, it is best to select a review team with suitable experience and knowl-



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edge. The team leader should have solid managerial and technical skills. To the extent feasible, the team leader should not be associated with the area in which the incident occurred.

CCPS (2003) provides helpful guidance on building and leading an investigation team.

> A thorough and accurate incident investigation depends upon the capabilities of the assigned team. Each member's technical skills, expertise and communication skills are valuable considerations when building an investigation team. This chapter describes ways to select skilled personnel to participate on incident investigation teams and recommends methods to develop their capabilities and manage the teams' resources. (p. 97)

Four examples of five-why application follow.

Example 1: Design Flaw

The written incident description reports that a tool-carrying wheeled cart tipped over while an employee was trying to move it. She was seriously injured.

1) Why did the cart tip over? The diameter of the casters is too small and the carts are tippy. This has happened several times but there was no injury.

2) Why weren't the previous incidents reported? We didn't recognize the extent of the hazard and that a serious injury could occur when a cart tipped over.

3) Why is the diameter of the casters too small? They were made that way in the fabrication shop.

4) Why did the fabrication shop make carts with casters that are too small? They followed the dimensions given to them by engineering.

5) Why did engineering give fabrication dimensions for casters that have been proven to be too small? Engineering did not consider the hazards and risks that would result from using small casters.

6) Why did engineering not consider those hazards and risks? It never occurred to the designers that use of small casters would create hazardous situations.

Causal/contributing factors: Hazard was not recognized by operations personnel; design of the casters resulted in hazardous situations.

Conclusion: I [the department manager] have made engineering aware of the design problem. In that meeting, I emphasized the need to focus on hazards and risks in the design process. Also, engineering was asked to study the matter and has given new design parameters to fabrication: the caster diameter is to be tripled. On a high-priority basis, fabrication is to replace all casters on similar carts. We set a 30-day completion date for that work.

I also alerted supervisors to the problem in areas where carts of that design are used. They have been advised that when deciding to report or not report an incident that did not result in injury, they are to be extra cautious. And, they have been advised to gather all personnel who use the carts and instruct them that larger casters are to be placed on tool carts and that, until that is done, moving the carts is to be a two-person effort. I have asked our safety director to alert her associates at other locations of this situation and how we are handling it.

Example 2: Materials Variation

Operations personnel report concern over injury potential resulting from conditions that develop when a metal-forming machine stops because the overload trip actuates. This scenario offers an example of how the five-why technique can be used to resolve hazard/risk situations before an incident occurs. The safety director met with the supervisor who is directly responsible for the work.

1) Why are you concerned? The electrical overload trip actuates very often when we use this machine. It gets risky when it stops in midcycle and the work needed to clear the partially formed metal adds risks that employees think are more than they should have to bear. Occasionally, that's okay; often is too much.

2) Why does the overload trip actuate? This is a new problem for us. We rarely had the overload trip actuate. It started after a new order for metal was received. We are told that the purchasing department thought that it got a good deal from a metals distributor, but what was delivered did not meet our specifications. This metal is not as malleable and workable, and the metal former struggles in the forming process. So, the overload trip actuates. Maintenance is furious with us because we have to call them so often.

3) Why can't the amperage for the overload trip be increased for this batch of metal? Our engineers say they don't want greater power fed into this machine.

4) Why do you have to call on maintenance so often? The rule here is that no overload trip is to be reset without a review of why it tripped and clearance from maintenance.

5) Why haven't you recommended to your operating manager that he meet with the engineer and maintenance manager to decide how to resolve the overload trip problem for this batch of metal? That's not easy for me to do at my level. But, it would be good if you could find a way to get that done.

Possible causal/contributing factors: Overexertion; machine actuating when cleaning the partially formed metal; fall potential; partially formed metal presents hazard in the handling process.

Resolution of this risk-related problem involves the purchasing department (with respect to future purchases), operations, engineering and maintenance. Often, risk-reduction actions require participation by several interrelated and integrated functions. It is also clear that the supervisor does not feel free to discuss a hazardous situation with his boss.

Example 3: Electrical Safety

The technician fixing a broken machine did not turn off the electric power and was electrocuted. Initially, the causal factor was recorded as the unsafe act of the technician who did not follow the lockout/tagout procedure.

1) Why would the technician take such a shortcut? He was under considerable pressure from production to get the machine back in operation.

2) Why would production put that much pressure on him? This machine is vital to the overall process and production was lagging. Some production people were idle and doing nothing.

3) Why did the technician not take the few steps needed to follow the lockout/tagout procedure? We checked and found that the lockout/tagout station was not nearby.

4) How far away was the station? More than 300 ft.

5) Why was the station located so far away? That's the way the system was designed. We have a lot of situations where the lockout/tagout station is not nearby. They have been discussed but it was decided not to move them.

6) How could this situation be resolved? Senior management is upset about this fatality. So, engineering and maintenance are preparing a list of all lockout/tagout situations that need attention. We have been told that the work will get done.

Causal factors/contributing factors: distance to the lockout/tagout station made it inconvenient to go there; management did not recognize the risks of not having lockout/tagout stations nearby; production's pressure to get the repairs finished.

Example 4: Poor Maintenance

A machine operator slipped, fell and broke a hip. Oil on the floor. Cleaned the floor. (These three sentences are exactly what was stated in the report for the incident description, the causal factors and the corrective action. Further inquiry followed.)

1) Why was there oil on the floor? A gasket leaked.

2) Why did the gasket leak? Bearings are worn on this machine and when it is stressed, it vibrates a lot. The vibration loosened the joint.

3) Why is the machine stressed? When production is at full pace, which is often, this machine just barely meets the demand.

4) Why haven't the bearings been replaced? We sent two work orders with no response.

5) Why hasn't maintenance responded? We have been through two cost reductions and maintenance is short staffed. They prioritize work orders and ours have not reached sufficient priority status.

6) Why hasn't the machine been replaced with one that can handle production at full pace? That has been discussed at department meetings, but we haven't been able to get approval.

7) How could this situation be resolved? Management has been alerted about this issue and the potential for similar problems with other machines that are not being properly maintained. We hope management adds maintenance staff. Our department head has submitted a request to acquire a machine with larger capacity.

Causal/contributing factors: leaking gasket; worn bearings; maintenance staff's inability to respond to work orders on a timely basis; and operating a machine beyond its capacity.

Some incident investigation experts criticize the five-why technique because it may not address management system deficiencies. If the discussions focus on why and how questions, such deficiencies emerge around the fourth inquiry. The results would be close to cause-and-effect relationships. Safety professionals must understand that when this technique is applied to complex operations, the results may indicate that a more sophisticated causal factor determination system is needed. For the five-why system to be effective, management must establish that it wants to be informed about the reality of causal factors.

Conclusion

When investigating incidents, safety professionals must consider the amount of time available and organizational limits. If the investigation process recognizes deficiencies in management systems, the place at which investigators stop may be at the realistic organizational boundary.

Consider the internally prepared report on the *Deepwater Horizon* explosion (BP, 2010). The executive summary contains the following terms: "the causal chain of events"; "possible contributing factors"; and "caused this accident." Here's an excerpt from the executive summary.

> The team did not identify any single action or inaction that caused this accident. Rather, a complex and interlinked series of mechanical failures, human judgments, engineering design, operational implementation and team interfaces came together to allow the initiation and escalation of the accident. Multiple companies, work teams and circumstances were involved over time. (p. 11)

The second sentence in the excerpt contains five subjects indicating management system deficiencies. If an investigation system requires in-depth inquiry to include identification of causal factors such as mechanical failures, human judgment, engineering design, operational implementation and team interfaces, the system stops at a high management level and causal/contributing factors are found, not created.

Some may suggest that investigations should continue further to determine how each management system deficiency came to be. While that would be nice to do, investigators could say that getting as far into management system deficiencies as the BP team did may be as far as internally employed investigators can practicably go due to cultural and organizational limitations. The BP report would receive a superior rating in relation to the quality of causal factors identified compared to the more than 1,800 investigation reports the author has reviewed.

If an investigation process determines how and why an incident occurs and identifies the deficiencies in management systems, the contributing factors (the root-causal factors if one elects to so name them) are identified.

Improving incident investigation quality is much more important than the terminology an organization adopts. The ultimate goal is to achieve superior investigations. If an incident's why and how are cited in investigation reports, the investigators will have determined the root-causal factors and arrived at an appropriate stopping point. If the system in place reveals multiple causal/contributing factors and it works, what the factors are called is of less significance. Safety professionals cannot let semantics get in the way of accomplishment.

If what an organization has in place is effective, it is best to stick with it. Although incident investigations may not achieve absolute certainty in determining root-causal factors, having recognized that uncertainty, safety professionals can give advice that can be practicably applied with respect to root-causal factors and the management system improvements required. **PS**

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