Safety Observations

How a National Laboratory Uses BBS to Improve Its Emergency Program

By Michael E. Cournoyer, Joshua J. Miller, Darril C. Stafford and Richard A. Norman

Data generated from a behavior-based safety (BBS) observation program supports an emergency planning and preparedness program (EPPP) by establishing a process that methodically searches for and eliminates the causes of flawed defenses in emergency operations. Results presented in this article are pivotal to the ultimate focus of this program, which is to minimize emergency operational events. By employing control charts, trends can be identified in safety observation data. This increases technical knowledge and augments operational safety.

Work at a nuclear research laboratory involves chemical and metallurgical operations with nuclear materials. Engineered barriers provide the most effective protection from radioactive materials and have been incorporated through architectural and structural design. Engineering controls at a nuclear research laboratory include differential pressure zones, high-efficiency particulate air filtration, gloveboxes and radiation shielding (Cournoyer, Gallegos & Wilburn, 2011). Although barriers are in place, they can fail (DOE, Office of Environment, Safety and Health, 2006).

IN BRIEF
- **A nuclear research facility's emergency planning and preparedness program (EPPP) minimizes or mitigates the consequences of an emergency incident.**
- **In an effort to reduce the consequences of an emergency incident, a behavior-based safety observation program focusing on identifying and eliminating at-risk behaviors was implemented.**
- **This article focuses on data collection from facility condition observations, incorporation of this information into an input metric and the resulting improvements to the EPPP.**

A nuclear research laboratory's EPPP augments these passive safety features by minimizing or mitigating the consequences of an emergency incident in order to protect workers, the public and the environment. A key element of the EPPP is to consider measures that lower the risk of emergency operations. The implementation of a BBS observation program focusing on identifying and eliminating at-risk behaviors is one of these measures.

BBS is the process of observing a worker's safe or at-risk behaviors. Observations provide direct, measurable information on employees' safe work practices. Safety observations then take BBS a step further by incorporating one additional element: conditions. The goal is that long-term improvement will be sustained by continuously reinforcing safe behaviors, identifying and eliminating potential organizational weaknesses, and building robust and redundant defenses within systems.

A detailed account of this approach to glovebox operations has been described previously (Cournoyer, Kleinsteuber, Garcia, et al., 2011). A glovebox is a sealed container that, when coupled with an adequate negative-pressure gradient, provides primary confinement. Built into the sides of the glovebox are gloves arranged in such a way that the user can place his/her hands into the gloves and perform tasks inside the box without breaking containment. Glovebox operations are any tasks in which a worker places his/her hands inside the glovebox gloves.

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Figure 1

Facility Conditions Observation Card

		Facility Conditions Observation			
1.0		**Walking/Working Surfaces**	**Safe**	**At Risk**	**Error Precursor**
	1.1	Aisles and passageways are kept clear and clean to the extent that the nature of the work allows. Housekeeping in these areas is vital to prevent trip hazards. Permanent aisles and passageways are appropriately marked.			
	1.2	Floors do not have trip hazards such as power cords, loose carpet or other items on floor.			
	1.3	Personnel access such as stairs, ramps and aisles have even or nonslip surfaces free from all trip hazards.			
	1.4	Stairs with four or more risers have stair rails or handrails on the down side of the stairwell.			
	1.5	Stair treads are reasonably slip resistant and stair nosings have a nonslip finish. Open side walkways such as loading docks or catwalks have hand and guardrails.			
2.0		**Floor and Wall Openings, and Catwalks**	**Safe**	**At Risk**	**Error Precursor**
	2.1	Floor openings are properly guarded (e.g., railings, toe boards) or covered.			
	2.2	Runways are guarded by standard railings on all open sides 4 ft or more.			
	2.3	Toe boards are on catwalks when tools, materials or parts are being used from an elevated surface.			

Note. *Partial facility conditions observation card.*

View the complete facility conditions observation card at www.asse.org/psextra.

As taught in *Human Performance Fundamentals*, expected behavior is established by management intentions (INPO, 2002). Concerning a nuclear research laboratory's emergency operations, this desired behavior is communicated through the EPPP. Human error is triggered by various conditions, including at-risk behaviors, which are actions that involve shortcuts, violations of error-prevention expectations, or simple actions intended to improve efficient performance of a task, usually at some expense of safety. However, these acts increase the likelihood of a bad outcome.

To engage employees in identifying and communicating at-risk behaviors, a BBS observation program was implemented: ATOMICS, which stands for allowing timely observations measures increased commitment to safety. Through ATOMICS, conditions and practices that contribute to minor incidents are being addressed in the expectation that serious incidents will be reduced.

Facility conditions observations are of interest in emergency management because they provide information on single outputs that contribute to the overall outcome, the single output being operating discipline. Operating discipline consists of the administrative and engineered mechanisms and error-prevention techniques adopted to prevent error and to recover from or mitigate the effects of errors. By tracking facility condition at-risk observations monthly, an input metric for operating discipline is created. Maintaining such a metric provides warnings before operating discipline goes completely out of control. The consequence for each at-risk observation is negligible to low. In addition, outcomes from observations occur at a level of quality for concern below that of management. In other words, the monthly tracking of at-risk observations is a leading indicator (Cournoyer, Lee & Schreiber, 2007).

A primary objective throughout the nuclear research lab is that operations be conducted in a safe, deliberate and controlled manner. Providing sound standard operating procedures (SOPs) and requiring workers to use them are among the most formal, direct and effective methods available to management to ensure that operations meet the U.S. Department of Energy (DOE) objective (DOE, HSS, 1998). Procedures provide management with a critical management tool to communicate detailed expectations for how individual workers are to perform specific tasks. With regard to emergency management operations, facility condition at-risk observation warnings can be controlled by SOPs. This article focuses on data collection from facility condition observations, incorporation of this information into an input metric and examples of how the use of this metric has improved the EPPP.

Development of an At-Risk Observation Input Metric

An account of the BBS process has been previously reported (Wieneke, Balkey & Kleinsteuber). Briefly, the program is designed to engage the workforce in implementing and utilizing its own safety initiatives. The process is based on having workers observe other workers and provide feedback about safe and at-risk behaviors. Observations typically take 10 to 15 minutes. Observations are strictly conducted under the conditions that no names are used and no blame is placed. The observer uses an observation card to track safe and at-risk behaviors. Figure 1 depicts an excerpt of an example facility card. ATOMICS includes five questions for performing observations:

1) I thought you were performing an at-risk behavior because . . .

2) Do you agree that you were at risk?

3) Do you have any control over the situation?

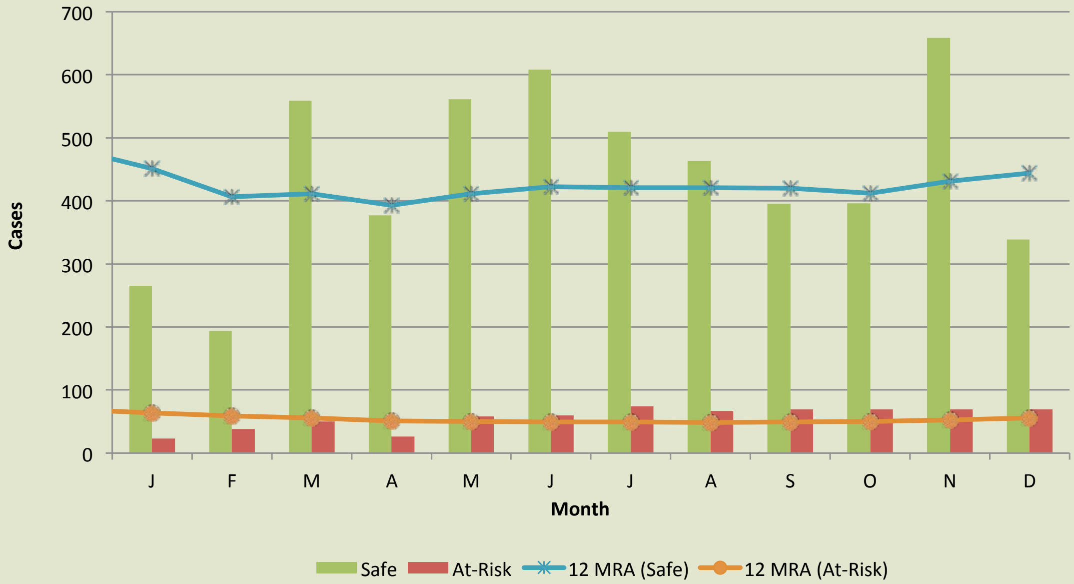
4) Do you have any ideas that could eliminate the risk?

5) Can this task be performed more safely in the future?

If an observer detects an at-risk action, especially if a safety system is being bypassed, the observer

Figure 2

Facility Condition Observations: Short-Term



Note. *Facility condition observations, January 2011 through December 2011.*

may question the observee to verify the intent and desired outcome before the action is taken. In addition, the observation is stopped if single-error vulnerability is uncovered. Single-error vulnerability exists when one mistake or slip will lead to personal injury or equipment damage.

Following an observation, the observer shares feedback and allows the worker to respond. Data from observation cards are entered into the ATOMICS database for analysis and problem solving. Results are recorded for trending purposes to help identify areas of strength and weakness. Before data analysis begins, comments accompanying at-risk behaviors are reviewed to ensure that the correct subcategories are populated. For example, if a floor with a trip hazard is documented, this should be recorded in section 1.2, which relates specifically to walking/working surfaces. If management wants more data from a specific category, this category can be targeted; that is, management requests more observations be performed in a specific category.

In partnership with the lab's continuous improvement program, the efficiency, cost-effectiveness and formality of emergency management operations are constantly being improved through the use of lean manufacturing and six sigma (LSS) business practices (Cournoyer, Renner & Kowalczyk, 2011). A useful LSS tool is statistical process control (SPC) (Prevette, 1999). This tool helps one collect, organize and interpret the wide variety of information.

For this study, ATOMICS data from facility conditions observation cards was compiled between March 2008 and December 2011. Precursors to error are unfavorable prior conditions that increase the probability for error during a specific action, that is, error-likely situations.

In Figures 2 and 3 (input metrics), the green and red bars represent safe and at-risk observations, respectively. The 12-month rolling average (MRA) is the average calculated over a 12-month period. For each month after this, the earliest value is dropped from the calculation and the most recent one is added, again to calculate an average over a 12-month period. The linear trend line (depicted in the metric as linear) is a best-fit straight line, starting from March 2008. The 12 MRA and trend linear plots are depicted as lines. Only the data from the last year are displayed for the input metrics.

A *u*-chart format was chosen to validate the variation of performance for the at-risk observations because the numbers of observations varies from month to month. The Poisson distribution is the basis for the chart. The following equations are used to construct the *u*-chart:

1) The average or baseline is calculated using:

$$\bar{u}_i = \frac{x_i}{n_i}$$

where $\bar{u}$ is the estimate of the long-term process mean established during control-chart setup.

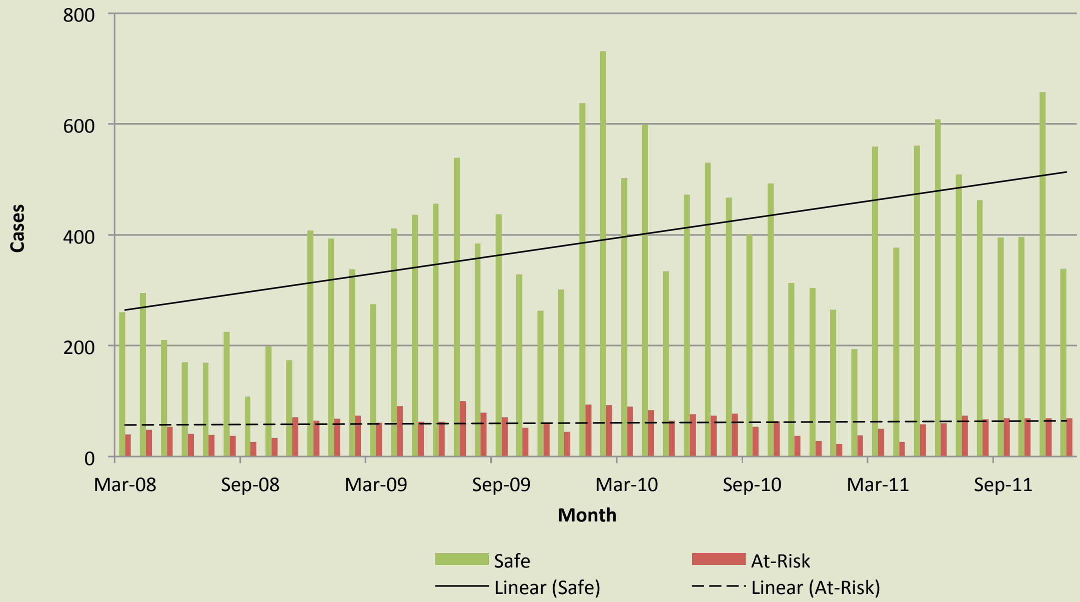
2) Upper and lower control limits (UCL, LCL) are calculated using:

$$\bar{u} \pm 3\sqrt{\frac{\bar{u}}{n}}$$

Control limits equate to three standard deviations. Upper sigma limits (1UCL, 2UCL) and lower sigma limits (1LCL, 2LCL) are calculated using one and two standard deviations, respectively.

Figure 3

Facility Condition Observations: Long-Term



Note. *Facility condition observations, March 2008 through December 2011.*

Causes of variation in a *u*-chart can be classified as random or systematic. Random causes in operating discipline are indicated by small intrinsic variations that are always present. Systematic causes in the operating discipline are signified by large variations or unswerving patterns that are identifiable and preventable. Operating discipline is considered to be under statistical control (stable) if all the variation is random, and out of statistical control (unstable) if the variation is systematic.

In general, 25 or more data points create a statistical baseline; the more data points, the sounder the statistical analysis. A trend is defined by the relationship of data points plotted on a control chart and are detected through preset rules. If a trend is detected, the special cause of the trend is determined. Trends serve as a notice that a special cause variation likely exists and adjustments to an EPPP may be necessary.

When a trend is identified, one must determine whether it is definitive, sigma zone or pattern. A definitive result occurs when one or more points fall outside the control limit. This is the case when outliers are present, and is the first test for an out-of-control process. A sigma zone occurs when a certain number of data points can be located in specific control chart zones. Patterns occur when a consecutive string of data show a pattern. Trends in this analysis are determined by the following criteria:

- one point outside the control limits (definitive);
- two out of three points; two standard deviations above/below average (sigma zone);
- four out of five points; one standard deviation above/below average (sigma zone);
- seven points in a row; all above/below average (pattern);
- seven points in a row; all increasing/decreasing (pattern);
- 10 out of 11 points in a row; all above/below average (pattern) (Cournoyer, Gallegos & Wilburn, 2011).

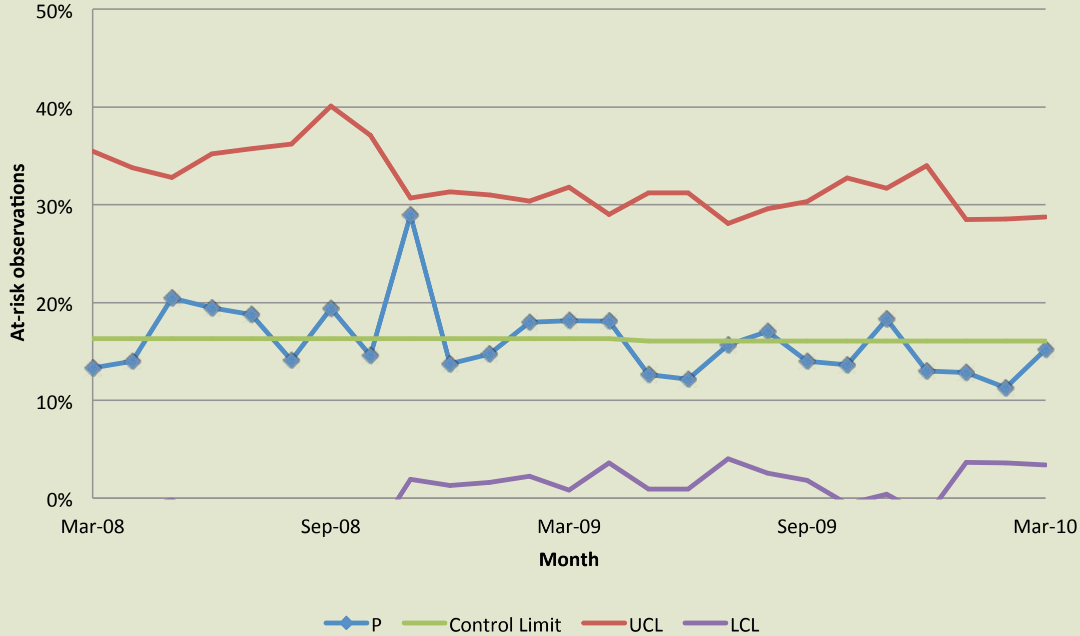
In the *u*-chart shown in Figures 4 and 5 (p. 66), the center line is green. One or more points meeting trend criteria are circled in red in Figure 5. Limits below zero are not shown. While all trends must be analyzed, patterns warrant a recalculation of the baseline and control limits. If a sigma zone exists, the corresponding sigma limit is displayed as a blue line. Performance from control charts is rated using the flow chart in Figure 6 (p. 67) (Costigan & Cournoyer, 2011). A preferred input metric generates data that fluctuate around a center line (Cournoyer, Renner, Lee, et al., 2011). Percentages of at-risk observations above the UCL are an indication that procedures are not being followed. Percentages of at-risk observations approaching zero may be an indication that pressure is being applied to discourage reporting of at-risk observations. The tighter UCL and LCL are, the more predictable the input metric is. The Pareto chart (Figure 7, p. 67) is employed to funnel through all at-risk observations and identify the critical categories. The left vertical axis is the ranking of occurrence. The right vertical axis is the cumulative percentage of the total number of occurrences.

Results

Facility condition observations were analyzed from March 2008 through December 2011. Facility condition observations are compiled in Table 1 (p. 67). Input metrics for the facility condition observations are shown in Figure 2 and 3. The number of facility condition observations for the past

Figure 4

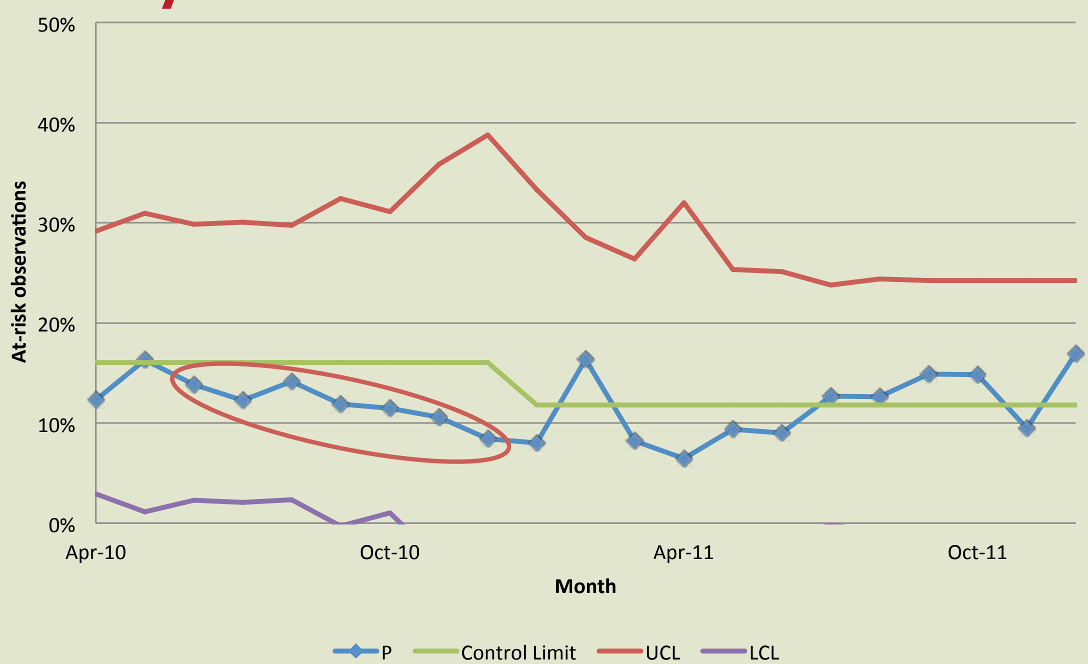
Facility Condition Observations: Baseline



Note. *Facility condition observations, March 2008 through March 2010.*

Figure 5

Facility Condition Observations: Current

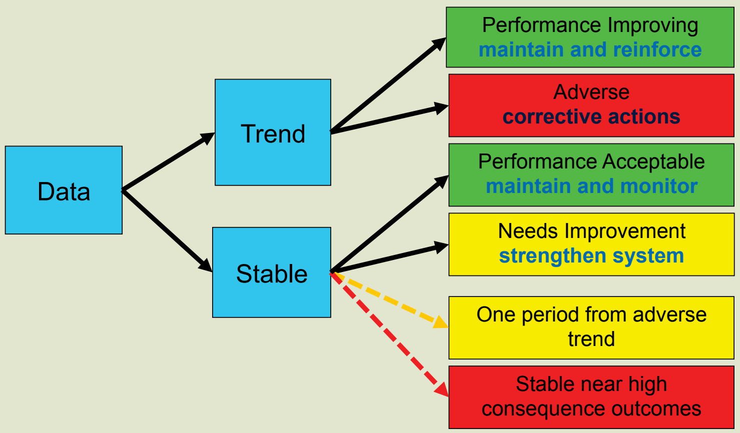


Note. *Facility condition observations, April 2010 through December 2011.*

12 months is 5,324 safe and 583 at-risk observations. The ratio of safe to at-risk observations is 9:1. Since March 2008, the number of facility condition observations is 17,891 safe and 2,700 at-risk observations. The greatest number of safe observations (731) occurred in February 2010. The greatest number of at-risk observations (100) occurred in July 2009. The long-term trends for safe and at-risk observations are flat and increasing, respectively. The ratio of safe to at-risk observations peaked at 18.9 in October 2011.

As discussed, the facility condition at-risk observations per total observations are tracked monthly. A baseline of 25 data points is established between March 2008 and March 2010 (Figure 4). The average percentage of facility condition at-risk observations per total observations is 16.1% with an average upper and lower control limit of 32.2% and 0.2%. A

Figure 6
Rating Performance From Control Charts



Note. *From "Improving Radiological Safety Using Statistical Process Control (LA-UR-11-11314)," by S.A. Costigan and M.E. Cournoyer, 2011, Los Alamos, NM: LANL.*

Figure 7
Facility Condition Observations: Pareto

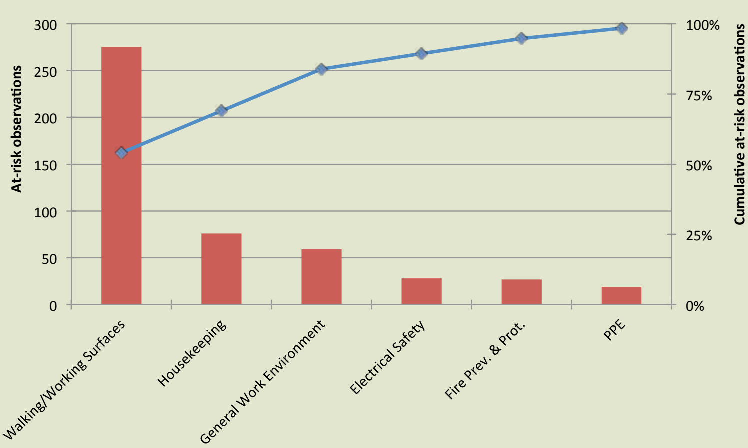


Table 1
Facility Condition Observation Results

Year	Safe	At-risk	Total
2008	2,218	455	2,673
2009	4,563	826	5,389
2010	5,786	836	6,622
2011	5,324	583	5,907

pattern occurs between June 2010 and December 2010: seven points in a row all below average (Figure 5). After correcting for the pattern, the average percentage of facility condition at-risk observations per total observations is 11.8% with an average upper control limit of 28.9%. Walking/working surfaces, housekeeping, and general work environment and indoor air quality make up 84% of facility conditions at-risk observations in the past 12 months.

Discussion

At-risk behavior is rarely penalized with an event or correction from peers or a supervisor (INPO, 2002). Instead, it is consistently reinforced with convenience, comfort and time savings. Workers typically perform at-risk behaviors because barriers to safe work often force them in conflicting directions. Removing these barriers requires identifying which barriers are causing at-risk behaviors. This is accomplished through observing and talking with employees. Individuals being observed prefer to receive concrete feedback on how they can improve. The feedback loop provides individual employees a method of hazard recognition and reporting that remains anonymous, with a built-in matrix to elevate safety issues for resolution as necessary. Furthermore, workers are more likely to avoid at-risk behavior if they know it is unacceptable. Workers and management should be aware of at-risk practices that occur, under what circumstances and on which systems (e.g., the EPPP).

Section 16 of the facility conditions observation card is the only section that relates directly to emergency preparedness (for the complete observation card from which Figure 1, p. 63 was excerpted, visit **www.asse.org/psextra**). Most of the other subcategories on the facility condition observation card relate to fire/life safety codes and industrial hygiene-type work, and have an indirect impact. The number of observations peaked in 2010 (Table 1).

The 12 MRA is a method of calculating central tendency over time, an attempt to even out short-term oscillations and identify trends. In the short-term, safe and at-risk observations have stabilized, (Figure 2, p. 64). This is a positive outcome. The linear trend line shows whether something is increasing or decreasing since the time that data were first collected, which is a good indication of past years' performance in the output metric. The number of at-risk observations remains steady, while the safe observations increase (Figure 3, p. 65).

No trends occur during baseline period (Figure 4, p. 66). The rate for facility condition at-risk observations is 11.8%; this is within management expectations (Figure 5, p. 66). The special-cause variation (pattern), due to a significant drop, is not considered adverse and requires no management action to reverse the trend. Forty-four data points were generated for the facility condition at-risk observation control chart. Thus, the observed trend is statistically significant.

Following the criteria in Figure 6 (p. 67), facility condition at-risk observation *u*-chart is stable, but needs improvement. Management expects to see fewer at-risk observations. The tighter the UCL and LCL, the more consistent the at-risk behaviors being observed. The negative control limits beginning in November 2010 are a concern; this indicates that an unacceptable number of facility condition observations are being performed. This is easily remedied by targeting facility conditions in the future.

The facility's defense-in-depth is its built-in capacity to detect or prevent errors without suffering undesirable consequences (i.e., its safety envelope). Redundant defenses improve safety margins, but also increase complexity. Flawed defenses and safety hazards become more difficult to detect. Without quality trending, defenses can degrade or be eliminated over time. The Pareto chart highlights the most important input parameters (Figure 7, p. 67). To reduce facility concerns, resources should be concentrated on walking/working surfaces, housekeeping, and general work environment and indoor air quality issues.

Redundant defenses make detecting program improvements more difficult as well. Based on the facility condition observations, no flawed defenses and safety hazards have been identified. This reflects management commitment to emergency operational safety and is indicative of the effort management has invested in this matter.

Nevertheless, management expects all emergency events to approach zero. Now that an effective input metric has been developed, goals can be set to adequately track the EPPP's performance. In this regard, lab management has set facility condition at-risk observations per total observations at 11%, which is lower than the current rate of 11.8%. Management will encourage more observations to achieve this goal. This should have the added benefit of tightening the UCL.

Collecting BBS observations gives management the additional information it needs to concentrate on vulnerabilities that require management support, while the consequences are negligible to low. As the observation input metric deviates from optimal, the lab's emergency operations can be improved through SOP revisions to bring them back into control. However, the frequency of observations should not be used as a predictor for future emergency management events; they only measure and monitor the EPPP concurrently.

The ATOMICS program accurately and objectively documents safe and at-risk behaviors and conditions. While the main purpose of the observation process is to provide opportunities to coach and reinforce safe behavior and to correct at-risk behavior, a secondary purpose is to identify opportunities to improve the organization of work. In-field monitoring of individual performance is an excellent way to gather information about how well management supports jobsite performance. **PS**

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