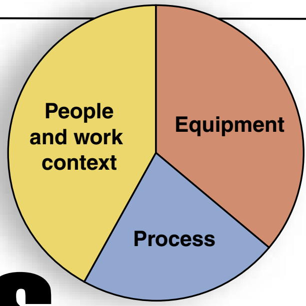
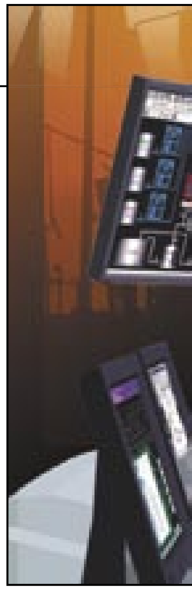
Cover Story

Prevent Plant Upsets



Factors contributing to abnormal situations:
- People and context factors — 35 to 58%
- Equipment factors — 30 to 45%
- Process factors — 3 to 35%



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Learn from Abnormal Situation Management to support future control room operators

For many years, the job of a control room operator at a petroleum refinery or chemical plant was seen as relatively simple: Keep the process running and fix it when it breaks. That perception is changing as more operators take on additional responsibilities for improving energy usage and process efficiency while maximizing production. Meanwhile, many companies have reduced the number of control-room operators as new process-control technologies have emerged, making today's operator responsible for running more areas of the plant in a safe and efficient manner.

Companies now recognize that they must prepare operators for their expanded roles by offering a diverse set of interconnected solutions in the areas of procedures, human-machine interfaces (HMI displays), automation and working environment.

The Abnormal Situation Management (ASM) Consortium is a group of chemical and refining companies, specialist service providers and universities that focuses on the complex human-system interaction and factors that influence safe and successful performance. ASM Consortium research has found that in plant upsets, human action or inaction — be it during the execution of procedures, maintenance practices, or engineering design — is almost always in some part of the equation. But it's never the only part.

Since the human element can never completely be removed from the equation, it's important to understand all of the events that lead to plant upsets and incidents, or "abnormal situations."

Underlying causes of plant upsets

Taking a holistic approach to studying plant upsets, the ASM consortium focuses on detecting and mitigating underlying causes that can lead to major incidents such as fires and explosions. Although it's difficult to determine a sole "culprit," ASM Consortium research identified people- and work-context factors as the culprit in 42% of the cases (Figure 1).

The other major culprits are equipment and processes. Each of these factors is almost always influenced by several underlying factors capable of turning a process upset into a disaster. Three of the most intensive areas of ASM Consortium research in this context are work environment, HMI design and alarm management.

WORK ENVIRONMENT

The operator work environment and communications are vital to managing abnormal situations. In fact, ASM Consortium research on effective communication and collaboration is central to many of the consortium principles. These principles address control-room design, console layouts, console adjacencies, traffic-flow patterns, sound abatement, lighting, room adjacencies and shift-worker fatigue. Some work-environment best practices are discussed below:

Console layouts and adjacencies

The control-room layout should be developed with a clear understanding of work processes and each operator's role. Console layouts should support the control-room communications strategy and allow operators to communicate freely during abnormal situations.

For example, remove walls that can block communication, or traffic patterns that prevent operators from easily gathering in a common location. Console height should be low enough that operators can see any overview screens or other sources of information without neck strain.

One operator may have responsibility over multiple consoles and should be able to freely move between them. An arc layout is ideal for this particular situation. In contrast, such an arrangement would be a poor choice for two entire teams of operators who mainly communicate within their respective teams. In that case, it might be better to have two reversed arcs and have the operators on the outside of each to minimize distractions.

Traffic-flow patterns

High human traffic can only mean distractions. For example, a control room in close proximity to the restrooms will encourage constant, unwanted traffic nearby, if not through, the control room. Choose console layouts that allow for traffic to flow outside the operators' scope of vision and hearing. Provide an area where a group of employees can gather to view information together without interfering with normal operations. Explore the use of large-screen monitors in these areas to provide overview information for operators and guests alike.

Sound abatement

Even in normal operating conditions, control rooms can be noisy areas. Manage sounds and noise effectively. Beneficial sound (such as alarm annunciation and operator-to-operator dialog)

should be channeled and isolated to specific areas and people. Alarm annunciation tones should be rationalized and strategically placed to sound in the vicinity of employees who need to take action. Location and placement of HVAC diffusers must also be designed so that there are no distractions caused by noisy building systems. Many companies are introducing sound absorbing material into control rooms such as fabric walls and carpeting, even fabric ceiling coverings, all of which will enhance NRCs (noise reduction coefficients).

Lighting plans

Improper lighting in a control room can cause eyestrain, distract operators, and prevent operators from viewing and comprehending important information. A comprehensive lighting plan must be developed in concert with the ceiling height, console layout and other functional requirements, and should include indirect sources that don't shine directly on operating screens. Introducing non-glare screens, such as flat-panel displays, also minimizes these impacts. Some consoles offer lighting that is focused onto a console-mounted work surface or a separate, nearby work surface to provide brighter light for reading documentation, without light shining onto the screens. Such well-designed lighting schemes can serve as a counter-measure to fatigue.

Improve communication

ASM Consortium research shows that communication gaps occur in the control rooms of many modern production plants. Shift handovers, for instance, tend to be problematic because of a lack of knowledge transfer between the departing shift and the new one. The departing shift might forget to tell the arriving shift a crucial piece of information about a valve being temporarily shut.

The use of electronic logs (e-logs) can ease this transition. When e-logs were introduced, they were touted as a way to replace handwritten logs and ensure that information was not lost during shift handoffs. The consortium found, however, that e-logs often simply replicate the paper logs that preceded them. Although entering data on e-logs is more efficient than a cryptic hand-written sentence, studies show that engineers and operators aren't taking advantage of features that improve operations, such as combining entries with trend data to give incoming shifts a better idea of how certain units have been performing.

Currently, the ASM Consortium is studying usage patterns, gaps between paper and electronic logging tools, and potential new ways to use e-logs to define requirements for a superior ASM e-log solution. The objective is to recommend product enhancements and guidelines that will result in more consistent shift handover, better site-wide awareness and better coordination amongst teams.

EQUIPMENT AND SYSTEMS

Besides making full use of ASM knowledge in the design of operator displays, ASM Consortium research has found that it is important to involve operators in the design process so that they understand the reasons for new approaches and have a chance to provide input.

HMI design

HMI design is one of the areas most intensively studied by the consortium. Interfaces designed with ASM Consortium principles are designed for proactive monitoring and capabilities to maintain a "big-picture" awareness of the plant, both of which play a major role in preventing abnormal situations. To develop context-relevant displays that suppress superfluous information, engineers and others involved in the design process must review normal and abnormal operating scenarios and assess what information and tools operators must be accessible to in each situation. HMI best practices include:

- ***Sparing use of color except to highlight critical, dynamically-changing information:*** When color is used correctly, operators will quickly notice anything that requires their attention. Display designers must carefully consider the use of color in displays that are primarily used for monitoring. For example, a fundamental rule is that it's better to use red for emergency alarms only, as opposed to using that same color for piping and fluid in vessels, in addition to emergency alarms. Keep in mind that there can be many forces driving inappropriate use of color; some operators may be accustomed to color conventions of older displays, for example.
- ***Integrated historical trending:*** ASM Consortium research has shown that, in general, operators who make use of trend displays tend to have a better understanding of what is happening in a process, and tend to more quickly spot a developing situations. It is therefore logical to integrate relevant (small) trend information into operating graphical displays to avoid the need for excessive call-up of other displays and to facilitate the view of relationships among the data. The same applies for other data depiction methods as well as historical trends.
- ***Hierarchal display configuration with multiple levels of increasing plant detail:*** For a set of operator displays to be effective, it is important that the navigation and hierarchy make sense to the operators. It is therefore necessary to carefully determine hierarchal levels, what type of information and level of detail should be shown on each, and how navigation between the levels should be achieved. When this is done effectively, operators can more quickly find the information and tools they need to deal with any situation.
- ***Integrated process-alarm management:*** Many operators still

HMI MATTERS — CASE IN POINT

In 2004, the consortium conducted a test with 21 professional operators at a large ethylene plant. The operators, each of equivalent skill level, were divided into two groups and were assigned to resolve simulated plant upsets. The first group used a high-quality, traditional operator display system where each of the eight screens in the simulator console used a single-window-per-screen approach, just like in their actual plant.

The second group was asked to solve matching scenarios with a multi-window ASM-style interface, which duplicated their actual plant interface and was specifically designed to improve situational awareness and response to changing plant conditions.

The results? On average, operators using the ASM-style interface detected events before the first alarm 48% of the time, as opposed to 10% for operators using the traditional interface. Additionally, ASM-interface operators took an average of 10.6 minutes to successfully complete the trials, whereas the traditional operators took 18.1 minutes. And, on average, ASM-interface operators successfully dealt with the situation 96% of the time; operators using the traditional interface had a 70% success rate. ❏

make significant use of dedicated alarm displays that typically have one line per alarm. Some of these displays work well for dealing with large numbers of alarms, but they epitomize a reactive mode of operation where operators spend an excessive amount of time simply responding to (or at least acknowledging) alarms, which takes the operator away from the process view of the situation. It is better to provide the alarm information on the normal operating display where it can be seen in context, and from where the operator can rapidly drill down through the level hierarchy to understand and respond to the alarm.

The above features allow operators to see a broad picture of the process, but also give rapid access to detailed information when necessary (for more, see HMI Matters — Case In Point).

Alarm management

Another area that the ASM Consortium has extensively researched is alarm management. Problems can include redundant alarms, chattering alarms, and standing alarms. DCS suppliers and third party companies have widely examined, recycled and publicized alarm management. The ASM Consortium has adopted a different approach; use existing, well-practiced Six Sigma methodology for this effort. The Six Sigma methodology of "define measure, analyze, improve and control" can facilitate effective alarm management. The following steps can help a site identify and improve its alarm-management strategy.

- ***Define the project basis and areas requiring improvement.*** Benefits are seldom expressed in hard dollars but can be inferred by using process incident statistics and operator productivity studies. Include an alarm philosophy that is a comprehensive strategy for developing, implementing and maintaining effective alarm practices. Ensure management has bought into the effort and the resources required to achieve the improvements.
- ***Measure your changes to showcase your improvements.*** Define the process, the inputs, the outputs and the key performance indicators (KPIs). These could include measurements such as time to respond to an alarm, number of alarms, or even incidents as defined by your company. Ensure that the data collection and analysis tools are in place to facilitate the specific investigation and problem you are trying to solve. The ASM Consortium and EEMUA (Engineering Equipment and Materials Users Association) have established best-practice guidelines for the more common metrics; average alarm rate less than one per 10 minutes for normal operation and less than 10 per 10 minutes for abnormal operations.
- ***Analyze the existing process using the output metrics as a base case.*** Identify "quick-hit" opportunities for improvement using Pareto charts or other statistical tools. With these tools, alarm "bad-actors" can be identified, yielding quick and quantifiable impacts for a minimal amount of effort. Studies have shown that process units can realize a 50% improvement in the alarm-rate metric with such an exercise when starting with a non-rationalized alarm database.
- ***Improve the process by implementing appropriate actions specifically targeted from the analysis.*** Alarm management improvement steps could include:
  - Addressing "bad-actor" alarms — alarms that appear most frequently over a period of time. The 80/20 rule generally applies and rationalizing a few "bad-actor" alarms (e.g. updating the alarm limits or adding a deadband) will yield a visible impact
  - Updating system/global alarm parameters that will address a large number of nuisance alarms such as disabling "bad input" alarms for all inputs that have no user-configured process alarm or no downstream connections
  - Utilizing console operator tools to temporarily allow the operator to disable nuisance alarms such as alarm inhibiting or alarm shelving
  - Implementing advanced alarming techniques available on the DCS such as alarm eclipsing and alarm debouncing.
  - Performing point-by-point alarm analysis, rationalization and update for the entire database. This will be the final step in the process and the most time intensive
- ***Control the process by implementing multi-disciplined teams.*** These teams should be specifically dedicated to managing the alarm strategies to realize and maintain the initial benefits, meeting regularly to promote continuous improvement. Keep management apprised of successes; make KPIs visible at all levels.

Research paves the way

The philosophy of the ASM Consortium is to match the technology with the operator's need as closely as possible; research is the key. ASM Consortium research points to three upcoming technologies that will enable future operators to better perform their jobs: mobile devices, early event detection and automated procedures.

Mobile devices: Mobile devices, which can be either hand-held PDAs or tablet PCs, are wireless extensions of the operator HMIs. Their value is in directly connecting field operators to the control room. Mobile stations allow field operators to see the same view as a console operator and to make faster, more informed decisions without having to utilize the console operator as the "middleman." These devices can also allow field operators to make changes to the actual process, a benefit during exercises such as instrument functional checkouts.

Mobile devices used for field operations can also greatly improve communications between various operating teams during normal and abnormal situations. When field personnel detect failing equipment or perform a manual startup task, that information is immediately available to all operators and computers on the network. It is also available for later review and possible identification of future improvements.

Early event detection: Early event detection (EED) includes techniques to identify undesirable events in advance of their occurrence, allowing operators to intervene sooner. Techniques such as multivariate statistical modeling are at the core of ASM Consortium research. This currently underused technology is an online mathematical model that interprets process inputs (in some cases, hundreds of variables) and identifies patterns that signify developing abnormal situations in realtime for the operator.

Automated procedures: Automated procedures facilitate startups, shutdowns and other process transients. Based in existing consoles/automation systems, automated procedures step the process through a predetermined series of field actions consistent with existing Standard Operating Procedures (SOPs). The main benefits are improved productivity through more consistent—and faster—execution of the procedure, as well as the elimination of human error and increased speed of execution.

No silver bullet

The anatomy of an abnormal situation can be quite complex and has many moving parts — from equipment malfunctions, to the dozens of alarms, to the operator who quickly acts to correct the problem. These situations must, therefore, be analyzed with a comprehensive viewpoint.

Likewise, there is no silver bullet to mastering abnormal situations. Yes, it's important to emphasize prevention and early detection of events, versus reactive mitigation, but it's equally important to emphasize factors such as control-room layout and its impact on communication between operators. Yes, it's crucial to use consistent graphics and colors within an HMI display — it's also imperative to make sure designated meeting rooms are available so that workers passing through won't disturb operators as they attempt to resolve an issue.

Abnormal situation management is a complex topic in process industries where the role of the control room operator is becoming more complex. Just as these operators must develop a holistic view of their plants, employers and engineers responsible for procedures and tools must have a keen understanding of the anatomy of an upset. The payoff could be millions of dollars and, possibly, a safety incident avoided. ■

Edited by Rebekkah Marshall

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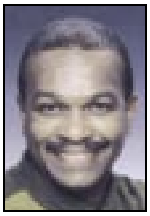

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Kevin Harris is a marketing and technology director at Honeywell Process Solutions (2500 West Union Hills Drive, Phoenix, AZ 85027-5139, Phone: 602-313-5985; Fax: 208-475-6394; Email: kevin.harris@honeywell.com). He has a B.Sc. in engineering science from the University of Southampton in the U.K. He has over 30 years of industrial automation systems and human-machine interface experience with Honeywell in the U.K., Belgium and the U.S. as a software engineer, engineering manager, product marketing director, business unit director and intellectual property director. In 1990, he sponsored the Alarm Management Task Force, which comprised Honeywell and several customers who wanted to improve the alarm management aspect of process upsets in industrial plants. Honeywell gave this customer group direct control of some R&D funds, and they worked closely with Honeywell engineers to direct developments. After the successful completion of this activity, several of the customers wanted to continue this work, but with a wider scope, embracing research and all aspects of Abnormal Situation Management. This group became the ASM Consortium.