ARC WHITE PAPER

By ARC Advisory Group

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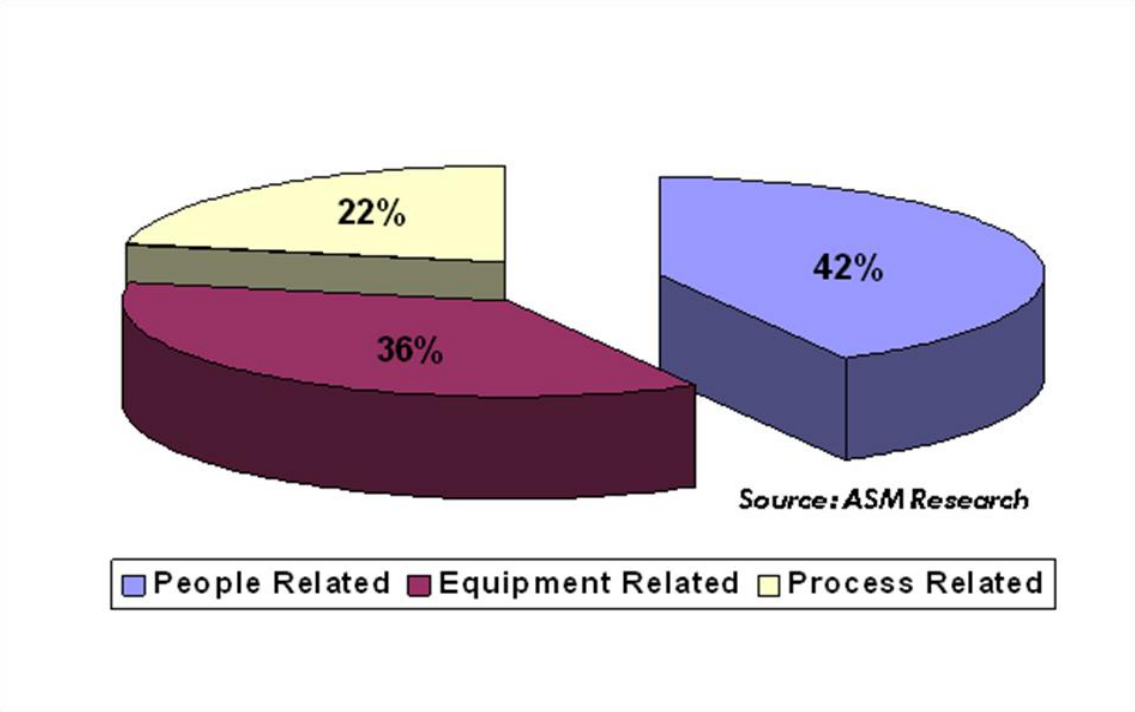
ASM Consortium's Solution Framework Creates Business Value for Adopters

Emergency	Major Incidents	Excessive Business Loss: Shut Down	No Production Fire, Explosion, Personal Injury, Environmental Damage	Operator Intervention; Safety Systems
Abnormal Situations	Minor Incidents	Business Loss: Return to Safe State	No Production Equipment Damage	
Abnormal Situations	Upsets	Lost Business Opps. Return to Normal	Little Production Off-Spec Product	
Normal Operations	Safe	Reduced Revenues: Constrained Operations	Reduced Revenues & Profitability Reduced efficiency	Regulatory & Advanced Control
Normal Operations	Target	High Profitability: Optimal Operations	Process Control Process Monitoring Procedures	

The business value of manufacturing operations is a function of various plant operating modes. The evolution of an abnormal situation from normal operations to emergency situations results in an escalating loss in business value.



Sources of Abnormal Situations

Executive Overview

Manufacturers in the process industries face a major challenge to maintain and improve margins. Closely linked to these business goals are the challenges to produce high quality products and achieve effective asset utilization. A problem occurs because of a company's inability to prevent or provide early detection of process deviations, excursions, and potential breakdowns or worse. Preventable anomalous process conditions or abnormal situations account for losses approaching three to five percent of a plant's total capacity each year. This translates into hundreds of thousands if not millions of dollars in lost revenues each year. Losses accrue not only from reduced throughput from unplanned shutdowns, but also from off-spec production, equipment damage, reduction in asset availability, disruptions to schedules, safety hazards, fines, litigation, and environmental remediation.

Billions of dollars are lost each year due to abnormal situations. Preventable abnormal situations account for losses approaching three to five percent of a plant's total capacity each year. Abnormal situations are difficult to detect and prevent because of complicated failure modes.

Abnormal Situations occur from disturbances that drive a process to deviate from its target and normal operating range. Abnormal situations fall outside the range of a control system's ability to manage and an operator must intervene. Most companies underestimate the scope of the problem that abnormal situations present. They erroneously believe that better training, monitoring, and alarms is enough to solve any problems. However, by their very nature abnormal situations are difficult to detect and prevent because of complicated multiple failure modes. Abnormal situations result from numerous sources throughout the entire design, operations, and maintenance lifecycle phases of an asset. Therefore, detecting and minimizing the effects of abnormal situations requires a thorough understanding of their root cause along with proficiency in multiple domains such as control, chemical, and human factors engineering to name a few. It also requires a structured approach to mitigate the effects of abnormal situations.

The ASM Consortium conducts fundamental research into the causes and develops guidelines and best practices to help companies deal more effectively with abnormal situations. Its mission is to empower operating teams to proactively manage their plants to maximize safety and minimize environmental impact while allowing the processes to be pushed to their optimal limits.

There is a large amount of research and best practices available on effectively dealing with abnormal situations, but most organizations are not aware of its existence. For example, the ASM Consortium conducts fundamental research to determine the causes of abnormal situations

and develops guidelines to mitigate their effects. The consortium has identified several domain or practice areas that need to be addressed to create effective ASM solutions.

Consortium member companies like ConocoPhillips and Sasol have contributed to the body of knowledge to understand abnormal situations and have developed and implemented solutions based upon the ASM Consortium guidelines and principles. Both companies have achieved significant benefits from participating in the consortium as well as reaping benefits from applying the principles and guidelines to their particular applications.

Purpose

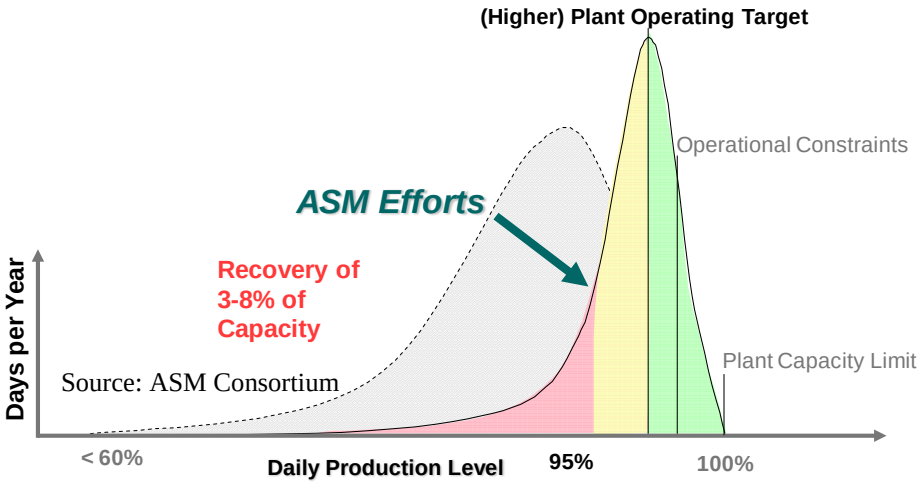
The intent of this paper is to provide a clear understanding of abnormal situations and the cost they have on manufacturers. The paper highlights the complexities and interdependencies of the causes of abnormal situations and why focusing on a single or couple of methods to prevent them ultimately fails. A more holistic approach is needed as outlined by the ASM Consortium, which is at the vanguard of conducting fundamental research and developing best practices to understand and prevent abnormal situations. The paper also illustrates the success two companies are having through their affiliation with the ASM Consortium to mitigate abnormal situations. These companies were chosen at random as other manufacturing member companies of the consortium share in their success as well.

Abnormal Situations are introduced at the edges of a control system's programmed limits, where the interaction between process elements becomes critical, and falls outside the control system's capacity to regulate. Operations personnel must identify these situations and execute a correct and timely response to avert detrimental effects.

Abnormal Situations: The Bane of Industry

Abnormal situations are caused by a disturbance or multiple disturbances that drive a process to deviate from its target and outside its normal operating state. The consequences of abnormal situations vary from minor process upsets that result in off-spec product and decreased throughput to major disturbances that cause unplanned shutdowns, equipment damage, environmental harm, and personal injury or even death.

The costs of abnormal situations are considerable. Major incidents and catastrophic events have cost the process industries billion of dollars in lost production, equipment repair, fines, and litigation. However, most incidents don't result in catastrophic failure but instead cause unscheduled downtime, poor product quality and other significant losses that, on average, cost companies roughly five percent of its capacity.



ASM Solutions Minimize the Affects of Abnormal Situations. This Results in an Increase in the Number of Days a Plant Operates at Higher Capacity thus saving $millions.

Abnormal Situation Are Difficult to Detect and Prevent

All manufacturers strive to keep their manufacturing processes on target. Unfortunately this is more difficult than it sounds. Detecting and preventing abnormal situations is challenging because of the use of increasingly complex processes, more sophisticated control strategies, and the integrated nature of processes and production planning.

Over the last couple of decades the role of operators have changed dramatically with automation assuming more responsibility while limiting the operators' perspective to smaller and smaller functional areas of the process. Operators only intervene in the process by exception – often managing from alarm to alarm. In addition, the loss of the complete "panel board" process perspective has reduced operators' situational awareness and understanding of interactions among various upstream and downstream units. Operators sometimes describe their jobs as long periods of boredom followed by moments of sheer terror.

Abnormal situations are not the sole responsibility or fault of the operators. Abnormal situations result from numerous sources throughout the lifecycle of a plant. For example, design flaws in a process or piece of equipment or inappropriate control strategies can create potentially dangerous incidents.

Abnormal situations develop and change over time making it more difficult to manage in an increasingly sophisticated and dynamic control room environment. In such an environment, human errors remain one of the largest contributing factors to abnormal situations. The growing complexity of processes and technology require more sophisticated tools and methods to prevent, detect, and mitigate abnormal situations. Fortunately, there are organizations that are dedicated to the promulgation of understanding and development of such tools and methods, like the Abnormal Situations Management (ASM) Consortium.

The ASM Consortium

The ASM Consortium consists of a group of companies from industry, universities, and consultants that focus on process industries operating issues. The organizations in the ASM Consortium collaborate to research and create knowledge, guidelines, work practices, tools, products, and human centered solutions designed to prevent, detect, and mitigate the detrimental effects that abnormal situations have on product quality, safety, and manufacturing production.

ASM Members

- BP
- ConocoPhillips
- ExxonMobil
- Honeywell
- Human Centered Solutions
- Mary Kay O'Conner Process Safety Center
- Nanyang Tech. University
- Penn State
- Sasol
- Shell
- UCLA
- UOP

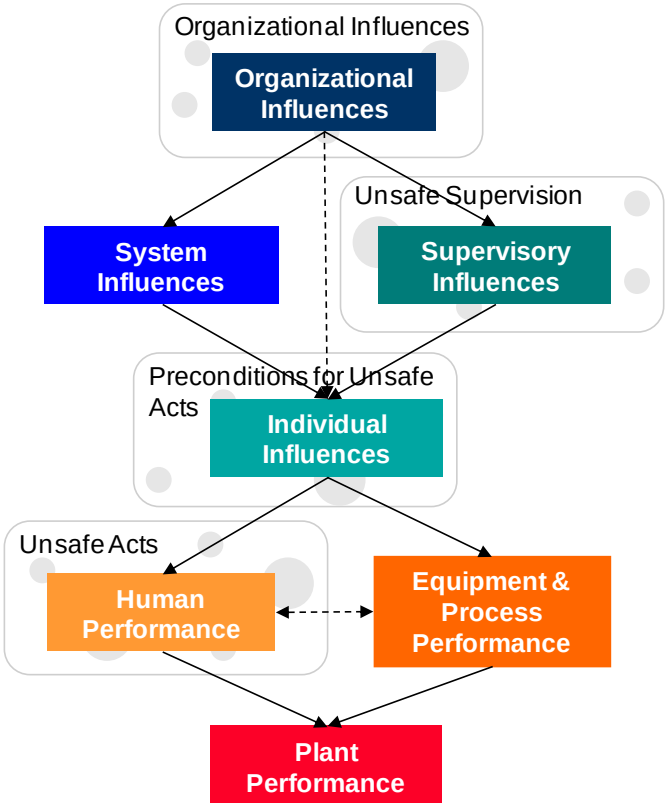
The ASM Consortium was officially founded in 1994. Members include BP, ConocoPhillips, ExxonMobil, Honeywell, Human Centered Solutions, Mary Kay O'Connor Process Safety Center, Nanyang Technological University, Penn State, SASOL, Shell, UCLA, and UOP.

Since its inception, the ASM Consortium has conducted comprehensive research at member sites to determine the root causes of incidents. In addition, the group researches more effective ways to detect early warning signs of abnormal situations so that better methods to avoid or at least manage deviations before they get out of control can be developed.

The knowledge the group has collected from research and real-world experience is grouped into seven practice areas that form a solution framework for the development of best practices, guidelines, and tools to assist operations teams. The intention of the consortium is to disseminate more of its research, information, and conclusions to the process industries.

ASM Framework and Research Areas

ASM Consortium research indicates that modern process automation and safety systems are capable of handling situations where a single mode of failure occurs. However, they do not perform well at preventing incidents where multiple failures occur at the same time. Consequently, no single solution is sufficient to prevent abnormal situations from happening. Instead, what is needed is a solution framework developed from actual knowledge of complex failure pathways and interactions.



ASM Cause and Effect Framework Improves Understanding of Abnormal Situations

The ASM Consortium has concluded that the majority of failure modes include human errors. However, the operator is rarely at fault. Therefore, a solution framework requires collaboration among various disciplines such as control and chemical engineering, human factor engineering and management sciences. It also requires a highly structured and focused approach that spans the seven practice areas of the ASM Consortium: improving understanding of abnormal situations to the effects of organizational structure, training, communications, work environment, process control and monitoring, and procedures.

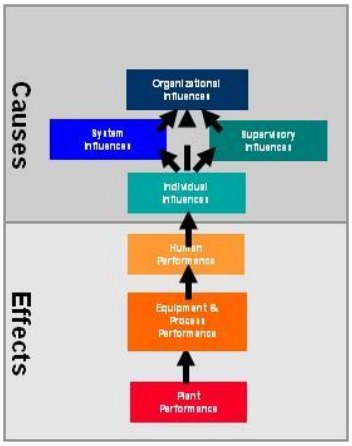
Understanding Abnormal Situations

The ASM Consortium has investigated numerous incidents to determine common causes and effects of abnormal situations. This increased understanding is an important element of any program aimed at mitigating and reducing them. In addition, the consortium understands how to measure, analyze, report, and communicate incidents so that metrics can be integrated into daily operations. The metrics allow companies to enhance manufacturing performance in real time by minimizing the affects of disturbances.

Organizational Roles

Management plays an important role in determining priorities, employees' roles and responsibilities, work practices, and cultural norms and behaviors within a company. Management is responsible for establishing organizational structures and continuous improvement programs that relate to abnormal situations. They are also responsible for providing leadership during abnormal situations.

Organizational Influences	System Influences	Supervisory Influences	Individual Influences	Human Performance	Equipment & Process Performance	Plant Performance
Policy	Experiential Learning	Oversight	Personal Readiness	Orienting Breakdown	Component Failure	Production Cost
Structure	Communications	Operations Planning	Mental State	Evaluating Breakdown	Corrosion Fault	Operating Cost
People	Knowledge & Skill Development	Problem Resolution	Physiological State	Acting Breakdown	Undesirable Chemical Reaction	Capital Expenditure
Culture	Procedures	Activity Authorization	Human Capacity	Assessing Breakdown		Loss Incidents
	Workplace Environment		Interpersonal Interaction			Employee Satisfaction
	Process Equipment					Customer Satisfaction
	Control & Information Systems					
	Management of Change					



ASM Cause and Effect Framework: Influence and Performance Categories

Operators and maintenance personnel play a significant role in averting abnormal situations too. The ASM Consortium examines organizational structures along with responsibilities, training programs, tools and applications, equipment preparation and procedures, and skills required to keep a plant running smoothly.

Knowledge and Skill Development

Developing both skills and knowledge of operators and other plant personnel improves their recognition and response to abnormal situations. The ASM Consortium examines ways to develop and maintain a competent work force through training and through a continuous learning environment. Among the methods examined include identifying effective areas of usage of low and high fidelity training simulators along with the advantages, disadvantages and benefits of each method.

Communications

Effective daily communication and exchange among plant personnel is imperative to enable better situational awareness during all modes of operation. How, what, and when are important factors of successful communication during normal, abnormal and emergency operations. The ASM Consortium is exploring the use and benefits of IT and other media to improve site-wide coordination of operational activities. Other research areas include examining the benefits of electronic logs and other shift handover communication methods.

Procedures

Developing, implementing, and using procedures are typical functions in most plants. Procedure development and use must be accurate, clear and comply with policy and intent so personnel can successfully accomplish their tasks – whether those tasks be during startup, shutdown, normal or abnormal situations. In addition, many companies are automating procedures to reduce human error. The ASM Consortium is investigating the factors that affect procedural development and deployment and is also looking at ways of dealing with situations that deviate from procedural in tent.

Environment

The appropriate work environment is conducive to improving operations situational awareness and performance during both normal and abnormal situations. Properly designed environmental work factors such as control room lighting, noise control, and operator console layout can improve operator situational awareness. For instance, dark control rooms can reduce the alertness of operators while too bright can cause glare and fatigue. A

poorly designed control room layout can also cause too much unnecessary traffic and distractions.

Process Control and Monitoring

Process control and monitoring is an essential activity in every plant. ASM research in this area focuses on effective design, deployment, and maintenance of a set of applications and tools that support process monitoring and control for effective operations during both normal and abnormal situations. The ASM Consortium has conducted considerable research in this area and is making its findings publically available as guidelines on "Effective Alarm Management Practices" and on "Effective Operator Display Design".

Dealing effectively with abnormal situations requires a holistic approach that spans multiple domain areas and addresses multiple failure routes. The ASM Consortium promotes a holistic approach by investigating several practice areas of operations that affect plant performance and developing strategies to prevent abnormal situations.

A Holistic Approach

Dealing effectively with abnormal situations requires a holistic approach that covers several domain or practice areas of operations due to the multiple failure routes. The ASM Consortium takes a holistic approach by investigating all practice areas that affect operations situational awareness and response strategies to effectively prevent and mitigate abnormal situations. Part of the goal of the consortium is to develop best practices and solutions in the form of guidelines and tools that improve operations, reduce human errors, and help companies respond effectively to deviations.

ConocoPhillips Joins ASM Consortium to Reduce Abnormal Situation Risks

ConocoPhillips, like many other process manufacturing companies, has had abnormal situations. A few of these situations have led to serious incidents such as fires and explosions. Around 1999, the Phillips Petroleum Company had an incident at its Houston Chemical Complex that resulted in severe equipment damage and personal injuries. Incidents like these can occur at any company, not because they are not safety conscious, but because the complex underlying contributing factors have not been well understood.

The Houston Chemical incident motivated the company to examine methods, procedures, and technologies that help prevent and better deal with

potentially dangerous deviations. ConocoPhillips started by bolstering its alarm management program, developing a Master Automation Program (MAP) and joining the ASM Consortium.

For ConocoPhillips, joining the ASM Consortium was an easy decision since the company has a safety conscious culture with many executive already involved with other international safety organizations. Keeping the necessary management involvement and support, however, requires constant bi-directional communications between plant personnel and executives. It also requires communications to keep important ASM initiatives moving forward at the plant level.

ConocoPhillips Identifies Areas for Improvement

Being an ASM Consortium member provides ConocoPhillips with a perspective on what other companies are doing to combat abnormal situations. The company stresses the importance of the high quality research conducted by the ASM Consortium, particularly in identifying root causes. Through its ASM Consortium affiliation along with its other initiatives, the company identified several important areas for improvement. These areas fall under the following domain or practice areas of the consortium:

- Process control and monitoring – emphasis on alarm management, and operator graphic displays
- Environment – human factors and control room design
- Procedures
- Organizational structure

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ConocoPhillips was able to justify its alarm management program based on lost profit opportunity (LPO), but the other areas, such as human factors or graphic layout, are more difficult to quantify. However, as a member of the ASM Consortium, the company was able to take advantage of the guidelines and best practices developed in several practice areas to augment their efforts and solutions in fighting abnormal situations. According to ConocoPhillips, its involvement with the ASM Consortium has allowed the company to improve its systems and programs faster while at the same time making them

more effective.

ConocoPhillips Starts with Lowest Performing Plants

Overcoming internal resistance of deploying new methods and solutions is challenging. ConocoPhillips started implementing ASM solutions at its lowest performing plants. These sites were chosen to erode internal resistance and influence other sites by demonstrating the value of ASM solutions. Alarm management, new control room design, and operator graphics were the first applications. The company established benchmarks for these sites, which fell in the bottom quartile. Within two years, the plants were performing at a much higher proficiency.

The company is now deploying alarm management, control room layout and visualization tools, and procedures at other sites. The company will share knowledge and lessons learned from the first deployment to aid in deployment at other sites. With the successful first deployment, operators are more apt to accept new graphic and procedure guides at their sites.

ConocoPhillips claims that although it is difficult to quantify benefits of applying solutions in some of the ASM practice areas, the company strongly believes that it has implemented programs faster than it could have without ASM Consortium involvement and that the solutions are targeted to truly reduce the number and severity of abnormal situations.

Sasol Uses ASM Framework to Mitigate Abnormal Situations

As is common in the process industry, Sasol has struggled with "alarm showers". In 2004, an initiative to formally address this problem was launched, with the stated intention of reducing instances where too many alarm events happen all at once. These occurrences are difficult to handle and often lead to operator mistakes. With the notoriety of numerous plant incidents taking place throughout the industry, Sasol wanted to be proactive and take preemptive measures to improve process safety. Initially, Sasol needed a way to rationalize its alarms and better train its operators. One of Sasol's suppliers, Honeywell, shared some of the ASM's concepts which fit the company's needs. As a result, one of Sasol's operating companies joined the ASM Consortium in 2006.

ASM Principles Adopted Throughout Site

Being a member at the site level as opposed to the corporate level gives the ASM team direct access to site resources. This allows quicker implementation and change cycles, since the site team is easily able to gain trust from operations. Interest and involvement from senior site managers assists in rolling out change.

One of the requirements of being an ASM consortium member is the contribution of new best practices. These are gathered in the form of an initial site audit, testing current company practices against the ASM framework described earlier. Sasol was able to use the results of this site audit to prioritize interventions that would maximize the impact from ASM practices. Initial focus was on alarm management, operator display, and operator training.

Without the research and guidance provided by the ASM consortium, deploying solutions to mitigate the effects of abnormal situations would take longer and be less effective.

Much of the efforts of developing and implementing ASM solutions within Sasol fall under the auspices of its automation community. This community has benefited significantly from being a member of the ASM Consortium. Without the research and guidance provided by the consortium, deploying solutions to mitigate the effects of abnormal situations would take longer and be less effective.

Since its initial alarm management implementation, the Sasol team has expanded its efforts beyond its original mandate to include other areas such as operator procedures, control room design and layout, organizational structure, communications, and early event detection. Justification was influenced by exposing local management to the high quality of research conducted by the ASM Consortium.

Research into industrial failures has generated a valuable database of root causes, specifically showing failure mechanism in the ASM framework topics. This research has created interest from several other parts of the organization, and the reliability, training and operational departments are becoming interested in applying ASM principles.

Solution Implementation Challenges

A major challenge for Sasol, or any company for that matter, is to implement fundamental changes to established procedures and practices. This is particularly true for abnormal situation management where few commer-

cial-off-the-shelf (COTS) product and solutions exit (although this is changing as several ASM Consortium supplier members are involved in developing and providing tools and products to fill the void). This is why Sasol finds the information, research, and guidance from the ASM Consortium invaluable. Sasol has realized that the expectation for a neatly packaged "silver bullet" is unrealistic, and that the company needs to expend time and effort to fully utilize the guidelines that have come from the consortium.

While much of the ASM Consortium's information is non-prescriptive, i.e. it does not provide step-by-step instructions for building solutions, it does provide useful guidelines that are applicable to a variety of circumstances. To take full advantage of the consortium's research, Sasol formed a group to use the information and tools available to develop and implement ASM solutions to meet its specific needs. For instance, the company developed several solutions and project methodologies including "Sasol HMI Design Guidelines" that incorporate ASM principles. In many cases, the company works closely with its suppliers, like Honeywell, and system integrators to develop solutions.

To take full advantage of the consortium's research, Sasol formed a group to use the information and tools available to develop and implement ASM solutions to meet its specific needs.

To gain acceptance within the company, the group worked closely with operators, trainers, supervisors and other plant personnel. The group explained why the solutions are designed a specific way to increase buy-in from the stakeholders. In addition, the company had appropriate site level management support and vigilance to ensure projects, solutions, and changes to underlying workflow, procedures, and processes are successful.

Sasol Takes Holistic Approach to ASM

Sasol has taken a broad approach to its ASM initiatives. The company is addressing all ASM practice areas, but has made more progress in some areas than others. For instance the company has made considerable progress in the process control and monitoring area by implementing alarm management, human machine interface (HMI), and early event detection applications and solutions that incorporate ASM Consortium tenets. Sasol has also made considerable progress in control room environment, knowledge and skills development, understanding abnormal situations, and ensuring organizational roles and responsibilities are clearly defined. They are currently underway in improving communications and procedures.

Sasol uses a variety of resources to implement their ASM solutions. The company relies heavily upon the ASM Consortium research. They use the Honeywell Experion platform, and have found that many of the ASM principles are well supported by the platform. Sasol does not only rely on Honeywell to deliver ASM type solutions, and often implements best-in-class third-party software that is evaluated through rigorous piloting.

ASM Initiatives Provide Significant Benefits

Sasol is achieving significant benefits from its ASM implementations. The company has had a four-fold reduction just in alarms. Through its early event detection program, Sasol has reduced failure rates and prevented abnormal situations from occurring. The company's ASM improvements in control room environment, process control and monitoring, HMI, and skills development along with its greater understanding of abnormal situations enables better allocation of human resources and a high-level of acceptance among plant personnel. For example, in one of its large chemical reactors, the company has documented evidence of preventing several abnormal deviations before they became a major problem.

Sasol is achieving significant benefits from its ASM implementations. Areas of improvement include a considerable reduction in its alarms, reduction downtime and equipment failure rates, prevention of abnormal situations that reduce overall plant performance, and better allocation of human resources to name several.

Each ASM solution has provided significant benefits. Some, in fact, have ROI's that have significantly exceeded 100 percent. Development and deployment of solutions vary in cost, time, and effort. For example, a typical ASM solution might take a year to rollout the first solution and then about three or four months for each successive implementation. For example, the company's alarm rationalization took a little more than a half-year while rolling the program site-wide took about 1 ½ years. Redesigning the company's HMI standards and philosophy took about four months while redesigning the control rooms took about two years. Implementing projects that comply to ASM principles definitely add additional cost, but this is more than compensated through later returns. During DCS system replacement projects, the HMI upgrade is normally bundled into the total project cost. Traditionally these graphics have not been rigorously designed to improve human performance, and this prevents many of the new system capabilities from being exploited. Through the application of ASM principles, a small additional expense (five to seven percent) allows additional production benefits to be realized from the functionality within the new DCS.

Lessons Learned

Sasol believes that a lot of its success is due to its "site member" status of the ASM Consortium. At the site, the automation and engineering staff have direct access to the decision-makers. As each successful implementation occurred, support from management got easier. As awareness of success has grown, other sites are anxious to replicate the adoption of ASM principles.

Sasol indicates that it would have been more costly and difficult to implement ASM Consortium principles without a modern control system. In fact, in some situations, like implementing an ASM compliant HMI on an old DCS, it is impossible. In addition, control systems that are unable to track or electronically give account of their alarm rates and settings, increase the difficulty of alarm rationalization projects.

Sasol believes that a lot of its success is due to its "site member" status of the ASM Consortium. At the site, the automation and engineering staff have direct access to the decision-makers. As each successful implementation occurred, support from management grew.

The site made a decision to upgrade their automation system to improve situation awareness and incorporate functionality like early event detection, improved graphics, and database synchronization. The company estimates that it would have cost an additional 10 percent to implement ASM Consortium principles in the seven practice areas if it had not used a modern DCS like the Honeywell Experion platform.

In the past, Sasol's operators used panel boards that gave them an overall perspective of the entire plant. As Sasol moved to CRT screens, it narrowed their operators' perspective and provided them with only a small window into unit operations. The adoption of ASM Consortium principles and new graphics has brought back the big picture and created better operator situational awareness.

Conclusions and Recommendations

Abnormal situations are a major problem for every company. They are costly in terms of lost production as well as damage to equipment, personnel and the environment. By their nature, abnormal situations are difficult to prevent, detect and mitigate due to multiple failure routes. Detecting

and minimizing the effects of abnormal situations requires proficiency in multiple domain areas.

The ASM Consortium conducts fundamental research to the causes of abnormal situations and develops guidelines to prevent or lessen their effects. The consortium has identified several domain or practice area that need to be addressed to create an effective ASM solution framework. The practice areas include:

- Understanding abnormal situations including failure routes and root causes
- Organizational structures necessary to keep the plant running smoothing and effectively deal with deviations
- Knowledge and skill development to ensure operating personnel have the ability to recognize and respond to abnormal situations
- Communications that enable improved situational awareness
- Factors that affect procedural development, deployment and adherence
- Work environment factors that promote operations situational awareness
- Process monitoring and control applications to ensure effective operations during both normal and abnormal operations.

Companies need to develop a plan to deal effectively with costly abnormal situations. Companies must first understand failure modes and causes that lead to abnormal situations, then develop and deploy solutions that cover the gamut of practice areas as outlined by the ASM Consortium's framework.

ConocoPhillips has been an ASM consortium member since 2000. The company relies on the research, guidelines and information from the consortium to develop its alarm management, operator graphic displays, procedure guidelines, and control room design. Based on ASM principles, the company indicates that it has achieved significant benefits from its alarm management program and that other areas have benefited from quicker and more effective deployment as well.

Sasol has been a member of the ASM Consortium since 2006. The company has adopted all of the ASM solution framework tenets (though to varying degrees) with considerable success in many areas. Sasol has made significant progress in its alarm management program, HMI graphic displays,

control room layout, and skills development areas. Most ASM solutions have provided a compelling ROI. The company has had a four-fold reduction in alarms, fewer plant trips, reduced equipment failure rates, and improved quality.

Without a doubt, companies need to develop a plan to deal effectively with costly abnormal situations. Companies must first understand failure modes and causes that lead to abnormal situations, then develop and deploy solutions that cover the gamut of practice areas as outlined by the ASM Consortium's framework. Organizations that need help, guidance, and benchmarking should consider joining the ASM Consortium or acquiring information and research they conduct. Joining the ASM Consortium also offers opportunities to influence and broaden research priorities and to share findings through publications, webinars, and other methods as well. For more information about the ASM Consortium, visit their website at www.asmconsortium.net

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Acronym Reference: For a complete list of industry acronyms, refer to our web page at www.arcweb.com/Research/IndustryTerms/

ASM	Abnormal Situation Management	**LPO**	Lost Profit Opportunity
CRT	Cathode Ray Tube	**MAP**	Master Automation Plan
COTS	Commercial-Off-The-Shelf	**PID**	Proportion Integral Derivative
HMI	Human Machine Interface	**ROI**	Return on Investment

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