Stretch in technology and gaps in process safety for the hydrocarbon industry

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Dr. Mannan is a registered professional engineer in the states of Texas and Louisiana and is a Certified Safety Professional. His experience is wide ranging, covering process design of chemical plants and refineries, computer simulation of engineering problems, mathematical modeling, process safety, risk assessment, inherently safer design, critical infrastructure vulnerability assessment, aerosol modeling, and reactive and energetic materials assessments.

Dr. Mannan co-authored the *Guidelines for Safe Process Operations and Maintenance,* published by the Center for Chemical Process Safety, American Institute of Chemical Engineers (AIChE). He is the editor of the 3rd edition, *Lees' Loss Prevention in the Process Industries;* he has published 137 peer-reviewed journal publications, two books, seven book chapters, 142 proceedings papers, 12 major reports, and 143 technical meeting presentations.

Dr. Mannan is the recipient of numerous awards and recognitions including the American Institute of Chemical Engineers *Service to Society Award*, the Texas A&M University Association of Former Students' *Distinguished Achievement Award for Teaching,* the Texas Engineering Experiment Station *Research Fellow,* the Texas A&M University Dwight Look College of Engineering *George Armistead, Jr. '23 Fellow.* In 2007, he was elected Fellow of the AIChE. In December 2008, the Board of Regents of Texas A&M University System recognized Dr. Mannan's contributions in teaching, research and service by naming him Regents Professor of Chemical Engineering. Dr. Mannan received his BS degree in chemical engineering from the Engineering University in Dhaka, Bangladesh. He obtained his MS and PhD in chemical engineering from the University of Oklahoma.

Oil and gas are contributing enormously to the quality of our lives in the 21st century, just as they were throughout the 20th century. With the economies in the various parts of the world expanding significantly, more energy sources are required by our society, and in the previous several decades, people have switched to offshore deepwater hydrocarbon reservoirs. Besides politics, current exploration and production are limited by the technology, for deeper wells, higher pressure reservoirs or crudes that are difficult to recover because of higher viscosity.

Innovative offshore technology must be developed to carry out deepwater production and operations. At the same time, these hazardous operations (i.e., deeper wells and higher-pressure reservoirs) are creating new and unique hazards. Along with the current attention on the Transocean *Deepwater Horizon* Oil Spill, the development of advanced technologies to ensure the process safety and operational reliability of offshore facilities is becoming extremely important.

Hazards offshore. At present, we face the challenge of how to prevent or control hazards of deepwater exploration and production. *Process safety is always an essential part of the oil and gas industry* and a core value that requires continual improvement. Regulations should be dynamic and ready to be modified based on occurring industrial issues. Accordingly, the government and offshore operators should develop comprehensive management programs or regulations that assess process safety and environmental hazards.

It is well known that offshore operations have a very special environment, involving drilling, production and transport, as well as emergency response to incidents. Offshore employees are faced with many different factors that increase their exposure to injury, such as poor weather conditions, high-pressure operations, chemicals and confined space. Due to the dangerous nature of offshore operations, employees typically have very demanding work schedules. Research and technology developments for operation in deep waters and high-pressure reservoirs are urgently needed.

The industry must develop theories, analytical techniques and technologies to improve the current offshore infrastructures from all sources of failure, including design, operations, management, natural disasters and intentional acts such as terrorism. The research should focus on theories and techniques that apply to the many process safety issues, such as structural integrity, layers of protection, offgas handling, drilling, risk assessment and consequence analysis, human error and safety culture. Test beds may include processing facilities and complex structures within the offshore infrastructure, transportation vehicles (e.g., ship, helicopter) and the marine environment.

The goals of offshore safety research include integration of the concepts of process safety into the design and operation of offshore platforms and to use this to improve safety performance such that the unit/process is not vulnerable to certain failures. Also, by identifying aspects of the system that are vulnerable (not resilient), the speed and efficiency of response to failures could be improved. Some relevant areas of research include:

Structural integrity of risers/pipelines. Risers and pipelines are subjected to different types of corrosion due to continuous loadings (fatigues) and their exposure to the marine environment. Research is needed to study corrosion behavior underneath the coating layer, to assess the integrity of particular structures and to develop coating/corrosion assessment criteria for service under extreme conditions.

Layers of protection. Many US offshore rigs are equipped with blowout preventer (BOP) casing shear rams to seal off an oil or natural gas well being drilled or worked on. However, the BOP is currently the only layer of protection within the system and it is vulnerable to single-point failure. Thus, research efforts are needed for developing/identifying multiple layers of protection.

Risk assessment and consequence analysis using CFD. Computational fluid dynamics (CFD) has gained widespread recognition as a powerful tool for risk assessment and consequence analysis. The very nature of infrequent and highly diverse disasters can make prediction of the likelihood and consequences of such events very difficult. The multitude of systems and structures involved requires a very broad multidisciplinary team to understand, evaluate, compare and plan for disastrous failures. Research is needed with regard to fluid-structure interaction (vibrations of risers, motions of floating platforms), flow around vessel hulls in the presence of current and wind forces, wave loads (slam and impact), tank sloshing and BOP (impact) facility siting.

Recovery of H_2S. Hydrogen sulfide (H_2S) is corrosive for carbon steels used in offshore structures and can lead to nervous disorders and acid rain. To remove H_2S, a process called gas sweetening and amine sweetening has been used for onshore processing facilities. This process removes H_2S from the feed and redirects it to other processes in the plant, where it is converted into elemental sulfur or sulfuric acid. However, the present process is limited by the operating conditions and requires additional units to be built, which makes it insufficient for the offshore facilities. Given the compact size of the offshore structures, there is a need to optimize the gas-recovery process for offshore facilities.

Resilient operation of deepwater drilling. During drilling, all materials drilled out need to be removed, i.e., transported to the surface, a process that is referred to as hole cleaning. Often, some material remains in the well. Due to the number of parameters influencing hole cleaning and the complex mechanisms involved, the phenomenon has not yet been fully understood. Integration of the concept of resilience to the drilling and hole cleaning processes is needed.

Human error and safety culture. Both human error and safety culture have been identified as contributing causes in industrial accidents, including offshore facilities. Assessment of the safety culture in every aspect of work in the organization, and development of a systematic approach to apply safety culture in the organization will lead to reduction of human errors.

Spills clean-up. Mechanical containment should be the primary line of defense against oil spills. However, this method is not effective in clearing a large spill area. Chemical and biological methods can be used in conjunction with mechanical means for containing and cleaning up oil spills. Dispersing agents are the most useful in helping to keep oil from reaching shorelines and other sensitive habitats. Biological agents have the potential to assist recovery in sensitive areas such as shorelines, marshes and wetlands. In this regard, research for new dispersants, including nano-surfactant technologies, is needed.

Meeting the challenge. Deeper wells, higher pressure reservoirs and crudes with higher viscosity have introduced hazardous operations in offshore facilities, thus creating new and unique hazards. Efforts should be made to expanding the current focal point from that of drilling and utilization of BOPs to include a more encompassing proactive prevention program requirement for all offshore operations. There are many possible ways in which disasters equal to or greater than *Deepwater Horizon* could occur in offshore operations. Comprehensive programs that include inherent safety considerations, multiple layers of protection, consideration of human factors, analysis of worst-case scenarios and emergency response planning are needed. Finally, major efforts that explore new technologies in various areas should be a high priority. **HP**