Engineering Design for Safety: Imagineering the Rig Floor

By MARK D. HANSEN
and EGILL ABRAHAMSEN

Historically, the closer to the wellbore (center of the well) roughnecks and service company personnel worked, the higher the potential for injury. This is usually due to moving parts, caught-between hazards, pinch-points and falling objects. On a drilling rig, many of these hazards are inherent at the point of operation. Over time, as a result of these hazard exposures, rig operators can incur both minor and major injuries—and, in severe cases, some have even lost their lives.

It has taken much imagination by field operators and innovative engineers to devise ways to eliminate many hazards found on the drilling rig floor. This combination of imagination and engineering—so-called "imagineering"—has greatly improved rig safety. For example, much rig equipment is now color-coded to identify where it is safe to handle.

Although helpful, if rig equipment were designed to be inherently safe, such markings would be unnecessary. Therefore, the best solution is to design out these hazards. Although this can be a daunting task, through mechanization, the industry has been able to implement new technology and use existing equipment to achieve this goal. In the oil-field industry, mechanization means automating mechanical functions that would otherwise be manually operated.

PLCs Bring Mechanization to Life

Programmable logic controllers (PLCs) are a key element in the mechanization process. PLCs allow various mechanical devices to be linked together and remotely controlled. PLC technology has seen tremendous development—similar to that seen in the computer industry.

A recent development is the use of Windows-based PLC software inside common industrial PCs to emulate the PLC. Furthermore, through use of Windows NT, the user can run several PLC programs simultaneously on the same computer. Interfacing these computers with mechanized equipment has been simplified through "field-bus" technology (much like in the process industry). Field-bus technology reduces extensive hardwiring, which previously was the only way to connect this equipment. Through PLC technology, equipment from various vendors can be connected into one fully integrated system and be controlled remotely. The result is an overall streamlining of rig processes. As a result, PLCs are helping to reduce workrelated injuries—much like they did in the process industry.

Mechanized equipment on the drilling rig has the following component groups: mechanized power tongs (Photo 1, top right) for casing, tubing and drill pipe; tong positioning systems for these mechanized tongs (Photos 2 and 3, center right); and the stabberless system (Photo 4, bottom right). Each piece may be operated separately or combined as a package.

The control system is the critical component in linking this equipment. The "soft PLC" (Photo 5, pg. 22) and universal remote control panel (Photo 6, pg. 22) analyze input from sensors and actuators to manipulate equipment. This achieves optimum performance time, auto sequencing and safety interlocking, while it simplifies the operation by removing workers from the point of operation, thereby eliminating their exposure to hazards.

In the past, controllers for rig equipment were custom-built for each application (based on conventional PLCs). The new remote control provides freedom and flexibility to "multitask" the control system for several applications (Figure 1). This new control system can also be integrated with the rig's instrumentation for anti-collision and operation.

FLEXIBILITY & SAFETY OF THE MECHANIZED TONG SYSTEM

The mechanized tong system is like a universal mount that holds several different pieces of equipment. It was designed to have the flexibility and versatility needed to meet rapidly changing rig requirements. For example, several new deepwater drilling vessels now use advanced racking systems (to rack drill pipe and casing) to improve safety and rig efficiency (Photo 7, pg. 23). These systems move on rails across the complete width of the rig floor (Photo 8, pg. 23).

Based on the authors' experience and according to data from OSHA 200 logs, the use of conventional tong suspension lines interfered with rig operations and presented a hazard. Through mechanization, this hazard has been eliminated. Mechanized tong carriers also allow rapid changes between different tong modules (Photo 9, pg. 23). This is critical as more customers demand safe equipment and operations.

HAZARDS OF STABBING PIPE

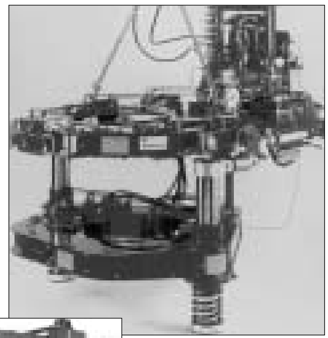
Before mechanization, pipe was typically aligned using a method called stabbing. The stabber manually aligned pipe threads of an upper joint so that it could be coupled by means of thread engagement to the pipe string already suspended in the well. The stabber also had to accomplish other physically demanding tasks, such as positioning, opening and closing elevators on the casing. S/he performed this job while tethered by a harness and standing on a stabbing board, some 30 to 40 feet above the rig floor (Photo 10, pg. 25).

This clearly is a vulnerable position. The employee is often exposed to severe weather conditions and his/her performance further impeded by poor visibility and communication. Consequently, injuries such as abrasions and lacerations to hands and fingers have been common in the industry (Abrahamsen). Severe injuries, such as finger amputations (caught between the pipe and the elevator), have been reported as well. In extreme cases, the stabbing board can be hit by the elevator or traveling block, leading to fatalities.

Due to these hazards, stabbing was clearly the most-hazardous job in rig operations—an assertion borne out by accident and fatality histories and job surveys. Prior to mechanization, the experienced stabber played a crucial role in the safe, efficient installation of a string of tubulars in a well. Here, communication with the driller was imperative. Any miscommunication or incorrectly positioned elevators could cause strings of pipe to be dropped, which would adversely affect both safety and efficiency.

STABBERLESS SYSTEM INCREASES SAFETY & SAVES TIME

The authors' employer engineered the hazard out of the stabbing operation, and now runs tubulars without exposing personnel in the derrick. The stabberless system combines a derrick-mounted hydraulic stabbing arm that features an electronic control system and other ancillary equipment needed to achieve this task. Although improved safety was the primary goal, efficiency has improved as well (Hollingsworth). This modular mechanized system can be easily integrated on most existing rigs—from small land-based rigs to large offshore vessels.



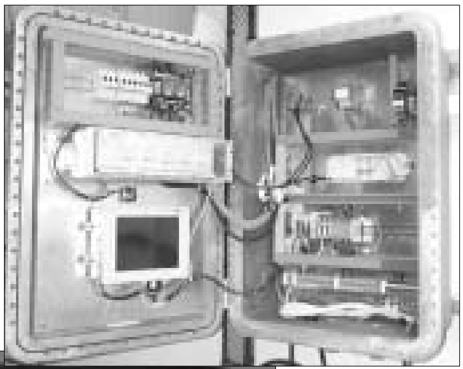
Mechanized equipment on the drilling rig has the following component groups: mechanized power tongs for casing, tubing and drill pipe (Photo 1, top); tong positioning systems for these mechanized tongs (Photos 2 and 3); and the stabberless system (Photo 4, left).

THE DRIVING FORCES

Four forces have driven rig mechanization: safety, economics, legislation and industry trends.

Safety

More than 30 percent of rig time is spent inserting or extracting (called "tripping") drill pipe or running casing and tubing (Abrahamsen). Investigations and accident analyses have shown that personnel involved in these activities are exposed to high risk. The repetitive and physically strenuous nature of the work increases the probability of error, which leads to injuries (and possibly fatalities). Mechanization removes the hazard by design and reduces



The “soft PLC” (Photo 5, right) and universal remote control panel (Photo 6, below) analyze input from sensors and actuators to manipulate the equipment. This simplifies the operation by removing employees from the point of operation.

the number of personnel working on the rig floor; in turn, this increases safety on the rig for the customer.

Economics

The average workers’ compensation (WC) claim on a rig is about $10,000—which can climb as high as $200,000 depending on severity. A claim in this range will quickly strip the profit of many drilling contracts. Thus, implementing a mechanized system clearly pays dividends while preventing employee injuries on the rig floor.

In times of intense competition and low profit margins—which the oil industry has experienced many times over the years—safety may contribute more to profit than a company’s best salesperson (Brennecke). Assuming an average profit on sales of three percent, a company must sell an additional $1,667,000 in product to cover the $50,000 in annual losses from injury, illness, damage or theft (Table 1). The amount of sales required to pay for losses will vary with the profit margin. With a one-percent margin, $10 million of sales would be necessary to pay for $100,000 of accident-related costs. The formula is as follows:

$$\text{Sales to offset losses} = \frac{\text{Dollars of losses x 100}}{\text{Profit margin (\%)}}$$

Furthermore, by reducing the number of employees on the rig floor, personnel costs can be reduced. Such costs include not only salary, but also all associated costs (e.g., transportation to/from location and onsite catering). In remote areas—such as off shore or in the swamps—these logistical costs can easily exceed a person’s salary. Therefore, reducing the number of workers on board reduces overall operating costs.

Rig time is another financial factor. Rig time is a crucial measurement because it is paid not in minutes but rather in seconds. This forces the industry to think in terms of saving seconds on repeated tasks. For example, a rig is running a particular size pipe (e.g., 360 joints of 9-5/8” casing) and can save an average of five seconds per connection. This adds up to 30 minutes saved rig time for that particular string. On some installations, that 30 minutes may be worth more than $5,000 net savings.

Conversely, high work speed increases injury risks—especially when manual work is involved. Rig mechanization may not speed trip time or the time to run tubulars; however, the consistency of the operating speed of automated systems combined with a safer work environment helps reduce costs. Mechanization makes it possible to initiate “offline” or “simultaneous” operations by use of modern derrick structures and pipe racking systems. Racking back stands of casing in the derrick while drilling reduces running time when these stands are run into the well.

The ultimate economic aspect, however, is the lifetime cost of the well. This includes handling, running and making up tubular with care in order to preserve pipe integrity. In some cases, fast is not equal to low cost.

Legislation

In 1995, the Norwegian Petroleum Directorate, the Norwegian authority responsible for the oil and gas industry, promulgated a regulation that required remote operation of all pipe handling (of tubular sizes up to 20 inches) between pipe deck and well center. This also included make-up and break-out of the pipe at well center, where workers had to stand away from the hydraulic power equipment during operation.

Had this regulation been immediately mandatory, most drilling operations in the Norwegian sector of the North Sea would have been shut down. However, the law allowed transition time so that alternative equipment, systems and procedures could be developed. If similar legislation were adopted worldwide, it would seriously affect the oil and gas industry.

Apparently, similar regulation may not be far off in the U.S. On June 21, 2000, the Dept. of Interior’s Minerals Management Service (MMS) released a proposed rule (30 CFR Part 250), “Oil and Gas and Sulfur Operations in the Outer Continental Shelf—Oil and Gas Drilling Operations.”

FIGURE 1 Schematic of the Control System

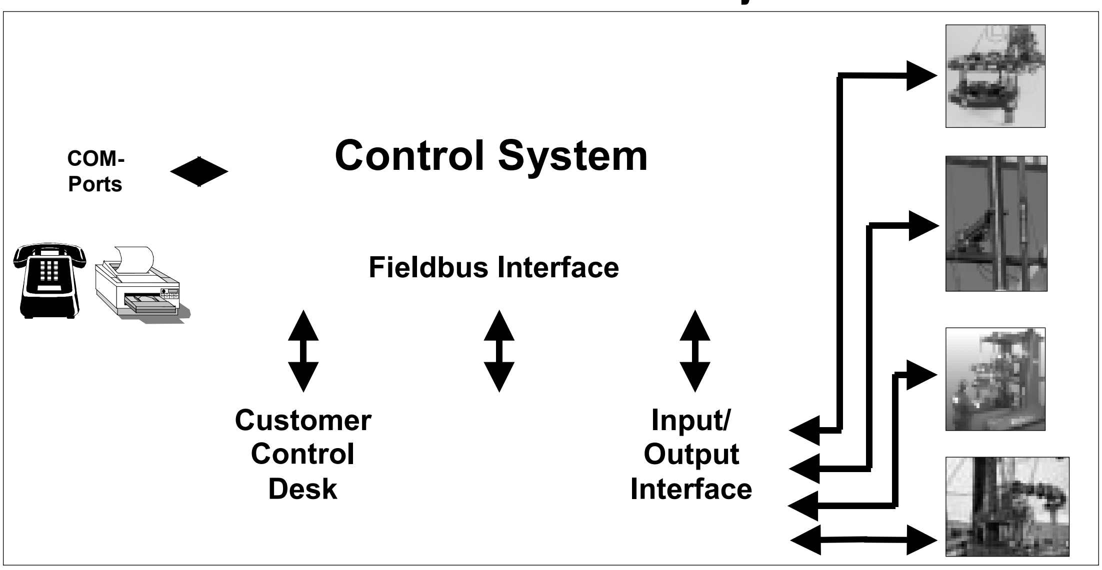


TABLE 1 Sales Required to Cover Losses

YEARLY INCIDENT COSTS	PROFIT MARGIN				
	1%	2%	3%	4%	5%
$1,000	100,000	50,000	33,000	25,000	20,000
5,000	500,000	250,000	167,000	125,000	100,000
10,000	1,000,000	500,000	333,000	250,000	200,000
25,000	2,500,000	1,250,000	833,000	625,000	500,000
50,000	5,000,000	2,500,000	1,667,000	1,250,000	1,000,000
100,000	10,000,000	5,000,000	3,333,000	2,500,000	2,000,000
150,000	15,000,000	7,500,000	5,000,000	3,750,000	3,000,000
200,000	20,000,000	10,000,000	6,666,000	5,000,000	4,000,000
SALES REQUIRED TO COVER LOSSES					

In times of intense competition and low profit margins, safety may contribute more to profit than a company's best salesperson.

The proposed rule states, "MMS is also looking at requiring drilling rigs to use automated pipe handling systems during drilling operations. MMS believes that the use of automated pipe handling systems clearly provides safety advantages over non-automated pipe handling systems. After further consultation with U.S. Coast Guard, we may propose this new requirement under provision 250.107, which mandates that the director require the use of best available and safest technology to protect health, safety and environment."

Clearly, the oil industry must adapt to the fact that the regulatory climate continues to be more stringent. Even the recently promulgated Ergonomics Program Standard will likely affect the way work is performed on land-based U.S. rigs. Innovative measures (such as rig mechanization) will be not only necessary, they also may be required to perform work on rigs in the very near future.

OSHA is also developing a "best practices" standard that will surely affect the industry. This standard is designed to ensure that management systems are implemented and safe work practices are completed for all potentially hazardous operations. It could impact the oil industry much like the Process Safety Management Standard (PSM) (OSHA 1910.119) did the process industries.

It should be noted that PSM carries an onerous paper documentation requirement for each of the 14 elements required for compliance. For example, implementing a process hazard analysis requires detailed analysis and documentation of process hazards. This includes all relevant process hazard information (e.g., engineering drawings, specifications, conditions, historical accident information, employee involvement and training).

Industry Trends

Decisions are not based solely on rational or measurable factors such as budget, time and efficiency; often, they are influenced by other parameters such as "spirit of the time." Mechanization and computerization are current industry trends and are increasingly being used to streamline operations and improve safety.

For example, many operators and drilling contractors now require contractors to control injuries on the rig floor. In fact, in some cases, low incident rates are a criteria for bidding on contract. Consequently, many are looking to engineering solutions as an effective way to design out hazards and prevent worker injuries.

Several new deepwater drilling vessels now use advanced racking systems (to rack drill pipe and casing) to improve safety and rig efficiency These systems move on rails across the complete width of the rig floor (Photo 7, above, and Photo 8, middle). Mechanized tong carriers also allow rapid changes between different tong modules (Photo 9, right).

The stabber had to align casing while tethered by a harness and standing on a stabbing board, some 30 to 40 feet above the rig floor (Photo 10, left). Thanks to imagineering, stabbing can now be accomplished using mechanized equipment (Photos 11 and 12, below).

Furthermore, regulatory agencies also consider what actions similar companies are taking to eliminate or minimize worker exposure to hazards. In some cases, the agencies view innovative techniques as the standard of performance—especially in the absence of consensus standards. In effect, rig mechanization "raises the bar" with a step-change improvement in safety by removing employees from harm's way while conducting operations.

CONCLUSION

As early as 1967, some in the industry recognized that eliminating the stabber's function would lead to reduced labor costs and increased safety. Integration of a stabberless system into rig operations is a step function improvement in rig safety and efficiency.

Thanks to the forces of safety, economics, legislation and industry trends, mechanization will continue to play a key role in the future of existing and newly designed rigs—and it is sure to lead the way to improved safety and efficiency. ■

REFERENCES

Abrahamsen, E. and D. Harris. "Mechanization of the Tubular Running and Handling Process." Presentation at the 1996 SPE/IADC Asia Pacific Drilling Technology Conference, Kuala Lumpur, Malaysia, Sept. 9-11.

Allen, H.G. and P. Scott. "Semi-Automated Drilling Rig." SPE 1378. Richardson, TX: SPE, 1996.

Azambre, J. "Accident Analysis: A Tool for Safety Management." Presentation at the First International Conference on Health, Safety and Environment, Nov. 10-14, 1991.

Boyadjieff, G.I. "The Application of Robotics to the Drilling Process." Presenta-tion at the 1988 SPE/IADC Drilling Conference, Dallas, Feb. 28-March 2.

Boyadjieff, G.I., et al. "Experiences in Automating in Pipe-Handling Functions." Presentation at the 1991 SPE/IADC Drilling Conference, Amsterdam, March 11-15.

Brennecke, R.A. "CEOs, VPP and the Bottom Line: Part I." Presentation at the ASSE 2000 Professional Development Conference, Orlando, June 25-28.

Brugman, J.D. "Automated Pipe Handling: A Fresh Approach." Presentation at the 1987 SPE/IADC Drilling Conference, New Orleans, March 15-18.

Defuillaume, J. and B. Johnson. "Drilling with Semi-Automatic and Automatic Horizontal Racking Rigs." Presentation at the 1990 SPE/IADC Drilling Conference, Houston, Feb. 27-March 2.

Croxford, J.F. "Advances in Automated Drilling." *Petroleum Review*. Oct. 1990.

"Oil and Gas and Sulfur Operations in the Outer Continental Shelf-Oil and Gas Drilling Operations." *Federal Register.* June 21, 2000: 38453.

Fos, C. "Full Automation Beckons for Drilling Facilities." *Offshore Engineer*. June 1990.

Hollingsworth, J.L. and J. Lorenz. "Eliminating the Stabber When Running Casing and Tubing: The Next Step in Rig Mechanization." SPE/IADC Paper 39383. Richardson, TX: SPE.

Jacques, M.E. and N.W. Herst. "Pipe-Racking Systems: Are They Cost Efficient?" Presentation at the 1991 SPE/IADC Drilling Conference, Amsterdam, March 11-14.

Kennett, B.J. and M. Smith. "The Design of an Automated Drilling Rig: RA-D." Presentation at the 1991 SPE/IADC Drilling Conference, Amsterdam, March 11-14.

Kinzel, H. and B.G. Pietras. "The Designing and Building of an All Purpose Automatic Torque Wrenching Machine for Drilling Rigs." Presentation at the 1992 SPE/IADC Drilling Conference, New Orleans, Feb. 18-21.

Kinzel, H. and J. Lorenz. "A New Approach to Mechanized Tubular Handling and Running as a Safe and Cost Effective Alternative." SPE/IADC Paper 37603. Richardson, TX: SPE.

Kozicz, J., et al. "New Generation of Semi-Submersible Rigs Is Engineered for Big Drilling Efficiency." Presentation at the 1999 SPE/IADC Drilling Conference, Amsterdam, March 9-11.

McGill, J. "The World's Most Advanced Platform Rig Troll." Presentation at the 1994 SPE/IADC Drilling Conference, Dallas, Feb. 15-18.

Mehra, S. and T. Bryce. "Innovative Technology for a Cost-Effective Land Rig." Presentation at the 1996 SPE/IADC Drilling Conference, New Orleans, March 12-15.

Merritt, G.H. "Systems Approach to Pipe Handling, Cementing and Mud Mixing." SPE 1729, Dallas, 1967.

"Operators Seek Ways to Cut Costs of Drilling." *Oil and Gas Journal.* July 30, 1999.

Ostebo, R., et al. "Risk Analysis of Drilling and Well Operations." Presentation at the 1991 SPE/IADC Drilling Conference, Amsterdam, March 11-14.

Peyon, A. and D. Harris. "New Developments in the Mechanized Running of Tubulars," SPE/IADC Paper 57589. Richardson, TX: SPE.

Price, M.J., et al. "Centralized Operations Control: A Driller's Cabin for the 1990s." Presentation at the 1988 SPE/IADC Drilling Conference, Dallas, Feb. 28-March 2.

Remson, D. "Planning Technique: Key to Drilling Efficiency." Presentation at the 1985 SPE/IADC Drilling Conference, New Orleans, March 6-8.

***Mark D. Hansen,** P.E., CSP, CPE, is director, quality, health, safety and environmental for Weatherford International Inc., Houston. Weatherford is an oil-field products and services company with more than 900 worldwide facilities and 10,000 employees. Hansen is currently ASSE's Senior Vice President. He holds a B.S. in Psychology and an M.S. in Industrial Engineering, both from Texas A&M University.*

***Egill Abrahamsen** is an applications engineer with Weatherford International Inc. A native Norwegian, he spent his early career in Norway with Weatherford; during this time, Abrahamsen was involved in the adaptation of legislation requiring remote operation of all pipe handling and makeup in that sector. He transferred to Houston in 1997 to spearhead Weatherford's focus on mechanization and provide global technical support for that process.*

READER FEEDBACK

Did you find this article interesting and useful? Circle the corresponding number on the reader service card.

YES	**33**
SOMEWHAT	**34**
NO	**35**