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Working Hard to Work Hard Safely

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Abstract

The shortage of qualified rig workers, and the desire of workers to earn high wages, is pushing drilling companies to increase the number of overtime hours. The trend in this growing industry of increased demand with limited numbers of workers is likely to continue. Unfortunately, another trend in this industry is an increasing number of work-related fatalities – with the Bureau of Labor Statistics reporting 98 fatalities in the oil and gas extraction industry in 2005. Historically, increases in the number of fatalities has followed the number of actively drilling rigs, even more so than the number of current employees. Working typical 12-hour shifts for 7 to 14 days in a row can lead to fatigue, resulting in mistakes in judgment and handling of equipment. Mistakes on a drill rig can be costly, both financially and in worker injuries. Fatigue is not unique to the drilling industry, and lessons learned from other areas can help identify and alleviate some of the potential hazards. Companies can schedule shifts and breaks to minimize fatigue, put in place policies and practices for identifying and managing fatigued employees, and help employees learn how to plan their off-time to minimize work-time tiredness. A summary of findings from research and practices in the oil and gas drilling industry as well as other industries will be presented with practical recommendations for safety management. The findings and conclusions in this presentation have not been formally disseminated by CDC/NIOSH and should not be construed to represent any agency determination or policy.

Introduction

The oil and gas extraction industry has a history of “booms and busts”, following the incentives of higher prices and the pressures of supplying a nation’s demands. These cycles of increasing and decreasing amounts of drilling activity correspond to changes in the number and rate of fatal injuries to the industry’s workers¹. This trend is evident over the last 13 years (Figure 1). There are many possible reasons for this

trend, including the influx of new, inexperienced workers during times of high activity and the longer number of days without a break that workers endure to make up for low staffing. While the data are inconclusive as to why these trends are occurring, safety managers and drillers should take these trends into consideration, and take steps to improve the safety of their workers through increased training, and countermeasures to prevent worker fatigue.

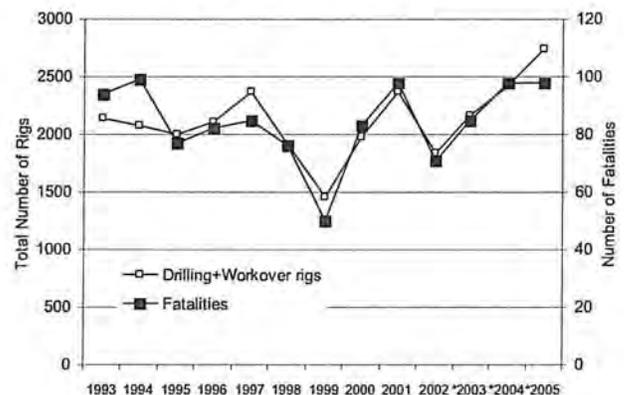


Figure 1. Total Number of Active and Workover Rigs (Baker-Hughes), and Number of Fatalities (Census of Occupational Fatal Injuries – SIC:13, *NAICS:211,213111,213112) for the Oil and Gas Extraction Industry, 1993-2005.

This paper reviews aspects of worker fatigue and explores ways for employers and workers to decrease injury risks due to fatigue from long work hours and working many days in a row. Past research from both the oil and gas extraction industry and others can provide useful guidelines and indicate areas for future safety efforts.

What is “fatigue”?

We have all felt ‘fatigued’ at some point from missing sleep, working long hours, or playing sports. Fatigue is the loss of strength, energy, and mental acuity that comes from hard mental or physical work and lack of rest. Similar to consuming alcohol, fatigue’s effects can be present before the person realizes that their abilities have become impaired². There is not a physical or chemical test that absolutely identifies or measures fatigue. It is defined based upon a set of conditions that lead to certain predictable physiological and performance effects. The conditions include time on task, time since awakening, acute and chronic sleep debt (cumulative sleep loss), and circadian disruption^{3,4}.

The effects of fatigue have been well documented and include slowed reaction time^{3,5}, decreased vigilance, and increased errors of omission⁴. Medical research has shown that observable performance reductions are preceded by decreases in attentional focus as measured by EEG brain wave changes and that even under high workload situations fatigued workers are unable to obtain the same brain activity levels as rested workers³. One indicator of fatigue is the occurrence of "microsleeps" – where a person momentarily slips into a light sleep state. This can occur with eyes open, and without the person being aware of it³.

Fatigue has also been correlated with an increase in occupational injuries^{3, 6-8}. Inattention, or lack of situational awareness due to decreased vigilance and microsleeps, can lead to hazardous situations for the fatigued worker and his surrounding co-workers. This relationship is most pronounced for night-shift workers⁹, when workers are performing tasks during a time when their bodies naturally would rest⁸. The disruption of natural sleep cycles is a disruption of the circadian cycle or internal clock which controls daily fluctuations in body temperature and the timing of sleep. A common example of this disruption is the feeling of 'jet-lag' that one gets when flying across multiple time zones, particularly when flying east. The moving of sleep times due to beginning or ending a series of night-shifts has led to the terminology 'shift-lag' and can result in the same fatigue and poor concentration¹⁰.

Fatigue is a primary concern in the transportation industry¹¹, especially trucking. Fatigue can be caused by both sleep disruptions and repetitive work without a break (even with appropriate levels of rest¹²). The Federal Motor Carrier Safety Administration has estimated that fatigue was involved in 15% of all fatal large-truck-related crashes. Other research determined that the number of hours driven had the strongest direct effect on crash risk¹³. Fatigue has also been shown to be an important factor in commercial aviation^{3, 4, 14, 15}, and mining safety¹⁶.

Within the oil and gas extraction industry, research and awareness about fatigue has mostly focused on the offshore sector, particularly within the United Kingdom^{6, 17-19}. Collins and his colleagues proposed that fatigue was a major factor in the cause of many incidents in the offshore oil and gas industry that have generally been attributed to 'human error'⁶. Many reports of injury incidents lack information about hours worked, day of shift, or hours slept during the previous 24 hours, that may indicate fatigue was a factor. In 50 reports from the US Coast Guard of injuries on mobile drilling units off the US Coast during 1996-2000 which considered it, fatigue was found to be a potential factor in 11 (22%; MSIS database).

The potential impact of fatigue should not be underestimated. Testing has shown that after 20-24 hours of wakefulness, cognitive performance decreases to a level equivalent to the performance of someone legally drunk - a blood alcohol concentration of roughly 0.10%^{5, 20}. As about

50% of night-shift workers do not sleep on the night before their first shift⁵, and levels of fatigue on subsequent nights may increase if proper sleep isn't regained, this poses a significant potential risk to workers and employers.

Solutions / Best Practices

Is fatigue a problem for my employees?

One of the first considerations for an employer is whether fatigue is an issue. In general, for any work situation where employees are working beyond the standard 8 am to 5 pm, regularly perform repetitive tasks, or if employees work beyond 40 hours a week, supervisors should consider how fatigue affects their workers' safety. Fatigue can also occur during a 'normal' work week, but it is a special consideration during overtime hours²¹.

While there is not one specific medical test for fatigue, there are several ways to measure how fatigue affects workers. These can either directly or indirectly measure fatigue, by assessing how fatigued a particular worker is (direct) or examining how a particular schedule or job might induce fatigue (indirect).

Direct measures attempt to quantify the level of sleep deprivation, tiredness, or lack of attention in a worker that represents fatigue. While special equipment is commercially available that can measure microsleeps and brain activity changes in motor vehicle drivers, these are impractical at an oil or gas drilling site. There are many paper-and-pencil measures of fatigue, although most were designed to measure fatigue associated with a particular disease process, e.g., chronic fatigue syndrome, cancer. Several self-assessment measures are available through Enform²² (www.enform.ca) which are appropriate for the oil and gas industry. These include a daytime sleepiness test (Epworth Sleepiness Scale; ESS), employee assessment form, and sleep debt calculator. The ESS is a widely accepted and easily used test to measure daytime sleepiness²³, as is the Karolinska Sleepiness Scale²⁴. The Energy Institute of London has published a report which includes guidance for the development of a company-specific fatigue questionnaire²⁵.

Indirect measures use previous research on sleep requirements, time-on-task, and injury rates to identify which work schedules are most likely to result in fatigued workers. A well known indirect measure is the HSE Fatigue Index (<http://www.hse.gov.uk/research/rrhtm/rr446.htm>) which uses information about commuting time, workload, attention required during work, and breaks along with a detailed work schedule to calculate both fatigue and risk indices²⁶. This index is most useful for examining the effects of rotating schedules. The authors specifically note that it should not be used for shifts worked offshore²⁷, and one may speculate that it would also not apply to work done on the North Slope in Alaska where workers temporarily reside at or near the worksite. In general, there is evidence for an increased relative risk of injury over successive workdays, and that this increase is substantially larger on the night shift than the morning/day shift²⁸.

Employers can assess the role of fatigue in their own health and safety program. A review of the rate of reportable injuries by hour of shift, and by day of hitch (work period) can indicate if fatigue is playing a role in the rate or severity of injuries. It is important not to only examine hour of the day, as this may mask fatigue effects that occur at the start of a hitch (coming back from time off), or near the end of a hitch (sleep debt which built up during the work period). When examining hour of the shift, the employer may need to examine the day-shift separately from the night-shift. The rate should be the number of injuries (e.g., reportables, loss time incidents) divided by the number of employees working during the time period examined. This is especially important when examining the effect of long hitches on worker safety. While the number of reportable injuries may be low for workers on their 20th straight work day, when you account for the lower number of workers that work a third straight week, the rate may be higher than during the first 14 work days. The Petroleum Safety Authority Norway found that serious occupational injuries on offshore facilities were more common during the second week of the work period when corrected for activity levels²⁹. Understanding the causes of injuries is the first step in preventing them.

Employers can also be aware of the rest needs of their workers. Supervisors know if they have workers that 'nod off' during lunch or break time, or have trouble the first night-shift of a hitch. While employees may request extra days of work, or give up time off, supervisors should remain vigilant for signs that fatigue is becoming a safety concern.

Can you 'manage' fatigue?

Medical studies show that the average person needs about 8 hours sleep a night (National Sleep Foundation). A poll by the National Science Foundation in 2002 found that the average American sleeps 6.9 hours a night (www.sleep-deprivation.com), indicating that the average American is working with a sleep debt.

The oil and gas extraction industry involves a 24-hour workplace, and current employee shortages are unlikely to allow for more employees working shorter tours and fewer hours per week. Given these conditions, employee fatigue can still be kept to a minimum through organizational support, and worker education. The safety of all workers depends on it.

Organizational Support

A survey of safety professionals in the offshore oil and gas industry found that workers viewed organizational elements such as training programs and the corporate safety culture as much more important to worker safety than external factors³⁰. In fact, corporate culture is a main driver in creating and maintaining a safe workplace in the oil and gas extraction industry³¹.

Organizational support for minimizing the effects of fatigue can consist of several activities starting with evaluating what effect fatigue is already having on worker safety. For companies which have an established health and safety

program, information gathered as part of an incident investigation should include information relevant to fatigue. It is important to remember that someone who was just injured or had a near-miss is unlikely to appear fatigued, even if they were before the event. Data can include shift length, number of days worked in a row, breaks during shift, rest between shifts, and the nature and demands of the job. A checklist and example accident investigation are included in the report on fatigue issued by the Energy Institute²⁵ and available online (www.energyinst.org.uk).

Organizational support also comprises risk assessment, or preventative measures. This includes appropriate scheduling, and assessing the risk associated with different work schedules. Scheduling should take into account the tasks of each occupation, the time of day it is occurring, and travel time to/from the worksite. Each rotation of the sleep cycle causes disruption, whether that rotation is during the work period (e.g., 7 night shifts followed by 7 day shifts), or during the rest period (e.g., coming off night shifts to a 7 day break). In general, schedules which require fewer adjustments are better for worker health¹⁷. One group reporting on shift scheduling for offshore oil and gas workers found that workers complained about adjusting back to night sleeping during their days off¹⁷. These complaints confirm that workers are affected by shifts in their sleeping patterns, and supervisors should consider how they affect safety.

Worker Education

While organizational support is key to eliminating the workplace risks posed by fatigue, workers can and should try to minimize its effects in their own lives. The first step is awareness of the signs and symptoms of fatigue, and knowing what behaviors can exacerbate the problem. Several groups including Enform (www.enform.ca) provide straightforward hand-outs on fatigue. They list common signs of fatigue such as yawning, vision blurring, inability to remember things you've just done, seen or heard; and list actions one can take to prevent the problem. The International Association of Drilling Contractors has created a safety meeting slide show specifically for fatigue during motor vehicle operation which is available on their website (www.iadc.org).

Several countermeasures can be effective in helping shift one's sleep times – or reset the circadian clock. Night-shift employees who worked in a brightly lit environment, wore sunglasses on the way home (during morning light), and had a dark sleeping area for rest, were able to shift their circadian clock and improve alertness and performance during their night shift³². The work area need not be 'sunlight' bright, just brighter than the light received during the drive home.

Conclusion

Oil and gas extraction is a 24-hour industry involving heavy machinery and hazardous substances. Shortages of experienced and available workers, and the physical location of some worksites makes a standard 8-hour workshift difficult. Given these constraints, employers might consider the potential effects that fatigue can have on their workers, and encourage workers to show up to the site well-rested. Several

ways that both employers and workers can minimize their risk of fatigue have been reviewed, and both employers and workers are encouraged to use the resources listed.

References

1. Curlee CK, Brouliard SJ, Marshall ML, Knode TL, Smith SL. "Upstream onshore oil and gas fatalities: A review of OSHA's database and strategic direction for reducing fatal incidents", Paper presented at the 2005 SPE/EPA/DOE Exploration and Production Environmental Conference, Galveston, TX.
2. Bourgeois-Bougrine S, Carbon P, Gounelle C, Mollard R, Coblentz A. "Perceived fatigue for short- and long-haul flights: a survey of 739 airline pilots", *Aviation Space and Environmental Medicine*, (Oct 2003) 74(10):1072-1077.
3. Battelle Memorial Institute. "An Overview of the Scientific Literature Concerning Fatigue, Sleep, and the Circadian Cycle." <http://cf.alpa.org/internet/projects/fdt/backgr/batelle.htm>. Accessed February 16, 2004.
4. Rosekind MR, Gander PH, Gregory KB, et al. "Managing Fatigue in Operational Settings 1: Physiological Considerations and Countermeasures", *Behavioral Medicine*, (1996) 21:157-165.
5. Dawson D, Reid K. "Fatigue, alcohol and performance impairment", *Nature*, (July 17 1997) 388(6639):235.
6. Collins A, Matthews V, McNamara R. "Fatigue, Health & Injury Among Seafarers & Workers on Offshore Installations: A Review", Cardiff, U.K.: Seafarers International Research Centre (2000) Research Project 461 Appendix 1.
7. Swaen GM, Van Amelsvoort LG, Bultmann U, Kant IJ. "Fatigue as a risk factor for being injured in an occupational accident: results from the Maastricht Cohort Study", *Occupational and Environmental Medicine*, (June 2003) 60 Suppl 1:i88-92.
8. Rosa RR, Colligan MJ. "Plain Language About Shiftwork" Cincinnati, OH: Department of Health of Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, (1997) DHHS (NIOSH) Publication No. 97-145.
9. Dembe AE. "Nonstandard shift schedules and the risk of job-related injuries", *Scandinavian Journal of Work and Environmental Health*, (2006) 32(3):232-240.
10. Scott A. "Shift work hazards", *Jacksonville Medicine* (Dec 21, 2006) www.dcmsonline.org/jax-medicine/2001journals/April2001/shiftwork.htm.
11. National Transportation Safety Board. "Evaluation of U.S. Department of Transportation Efforts in the 1990s to Address Operator Fatigue", Washington, D.C.: NTSB (1999) NTSB/SR-99/01.
12. Peiris MTR. "Frequent lapses of responsiveness during an extended visuomotor tracking task in non-sleep-deprived subjects", *Journal of Sleep Research* (2006) 15(3):291-300.
13. Pratt S. "Work-related Roadway Crashes", Cincinnati, OH: National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, (2003) DHHS (NIOSH) 2003-119.
14. Conway GA, Mode NA, Berman M, Martin S, Hill A. "Flight safety in Alaska: comparing attitudes and practices of high- and low-risk carriers", *Aviation Space and Environmental Medicine*, (2005) 76(1):52-57.
15. Goode JH. "Are pilots at risk of accidents due to fatigue?" *Journal of Safety Research*, (2003) 34(3):309-313.
16. Heiler K, Pickersgill R, Briggs C. "Working Time Arrangements in the Australian Mining Industry". Geneva: International Labour Office; 2000.
17. Miles R. "Developments in the understanding of working on extended nights offshore", Prepared for Society of Petroleum Engineers International Conference on Health, Safety, and the Environment, (2000) Stavanger, Norway 26-28 June (SPE 60996).
18. Sneddon A, Mearns K, Flin R. "Safety and situation awareness: 'Keeping the bubble' in offshore drilling crews", Prepared for Society of Petroleum Engineers International Conference on Health, Safety, and the Environment (2006) Abu Dhabi, U.A.E., 2-4 April (SPE 98629).
19. National Offshore Petroleum Safety Authority. "Safety Alert 06: Fatigue" www.nopsa.gov.au/alert/alert06.asp. Accessed 4 Jan 2007.
20. Lamond N, Dawson D. "Quantifying the performance impairment associated with fatigue", *Journal of Sleep Research*, (Dec 1999) 8(4):255-262.
21. Grosch JW, Caruso CC, Rosa RR, Sauter SL. "Long hours of work in the U.S.: Associations with demographic and organizational characteristics, psychosocial working conditions and health", *American Journal of Industrial Medicine*, (2006) 49:943-952.
22. Enform. "Fatigue Management: Enform Guide to Safe Work" Calgary, Alberta: Enform (2003).
23. Johns MW. "Sensitivity and specificity of the multiple sleep latency test (MSLT), the maintenance of wakefulness test and the Epworth sleepiness scale: Failure of the MSLT as a gold standard", *Journal of Sleep Research* (2000) 9:5-11.
24. Akerstedt T, Gillberg M. "Subjective and objective sleepiness in the active individual", *International Journal of Neuroscience*, (1990) 52(1-2):29-37.
25. Energy Institute. "Improving Alertness Through Effective Fatigue Management" London, England: Energy Institute (2006).
26. Health and Safety Executive. "The Development of a Fatigue/ Risk Index for Shiftworkers" London, UK: Health and Safety Executive (2006) Research Report 446.
27. Health and Safety Executive. "Fatigue and Risk Index Calculator Version 2.2, User Guidance" London, UK: Health and Safety Executive, UK (2006).
28. Folkard S, Lombardi DA. "Modeling the impact of the components of long work hours on injuries and 'accidents'" *American Journal of Industrial Medicine* (2006) 49(11):953-963.
29. Lauridsen O, Bjerkebaek E, Danielsen I, Loland G. "Work hours and serious occupational injuries", Prepared for Society of Petroleum Engineers International Conference on Health, Safety, and the Environment, (2006) Abu Dhabi, U.A.E. 2-4 April (SPE 98614).
30. Attwood D. "Offshore oil and gas occupational accidents - What is important?", *Journal of loss prevention in the process industries*, (2006) 19(5):386-398.
31. Schwall G, Nealis P. "Safety is not No. 1; It's a core value", Prepared for the International Association of Drilling Contractors and Society of Petroleum Engineers Drilling Conference, (2006) Miami, FL, 21-23 February (IADC/SPE 98956).
32. Revell VL, Eastman CI. "How to trick mother nature into letting you fly around or stay up all night", *Journal of Biological Rhythms* (2005) 20(4):353-365.