Fatigue risk mitigation

In the current excitement over nuclear new-build, all players, from engineering firms to construction companies to operating companies and regulatory agencies need to focus on the human factors that will ensure the safety and security of the industry. Resolving human fatigue risks, in particular, requires good risk management, good safety management, and also sound business leadership. By Susan Koen

The particular parts of the brain that suffer from fatigue are the four lobes of the cerebral cortex—the parts of our brain that control cognitive processes like reasoning, planning, problem solving, pattern recognition, auditory discrimination, visual processing, memory and speech. The primary root causes of this so-called cognitive fatigue are insufficient amounts of and/or poor quality of sleep in either a given 24-hour period (acute fatigue) or across multiple days (cumulative fatigue). The likelihood of such sleep deprivation is also heightened by circadian rhythm disturbances, which are common among night-shift, early-morning-shift and rotating-shift employees across all occupational classes, including salaried supervisors and engineers.

In turn, mild to severe sleep deprivation results in mild to severe levels of cognitive fatigue, with accumulating risks of performance errors on a wide range of cognitive tasks as sleep quantity and/or quality decline. For example, a 2009 study [1] found that subjects who reported 5-6.4 hours of good-quality sleep in the last 24 hours or as a cumulative average over the past seven days had a 230% greater relative risk for errors than subjects with 6.5-8 hours of good-quality sleep. When the amount of good-quality sleep dropped below five hours, the relative risk for errors was 490% greater than the control subjects. And, if the quality of sleep was reported as poor, the relative risk rate nearly triples, independent of sleep duration.

Studies of cognitive fatigue risks also have demonstrated that impairment from sleep loss at mild to severe levels is comparable to alcohol intoxication levels ranging from 0.04 to 0.12% blood alcohol content (BAC), respectively [2, 3]. In one Australian alcohol-comparability study [4], performance levels of the same 39 subjects were measured under both test conditions, sleep deprivation and alcohol intake. (The sample consisted of 37 men and two women; 14 were under 30 years old, two were over 50, and 23 were between 30-50 years old). The study used a crossover randomized control design with the order of testing counterbalanced, so half the subjects were exposed to increasing alcohol consumption first and the other half to increasing sleep deprivation first. Five separate testing sessions occurred with each subject for each condition. Breaks occurred after each testing to ensure sufficient sleep recovery, with comparable hours of sleep (average 7.3 hours) before each test.

Eight well-established computerized performance tests were used to measure seven different performance categories—passive vigilance, simple reaction time, visual tracking, dual task, perceptual coding, memory (two tests), and logical reasoning. At a BAC of 0.10%, legally drunk in almost all countries around the world, performance was poorest for all measures for all tests; it was twice as bad as a BAC of 0.05%, and up to seven times poorer than the baseline of zero alcohol intake. The study also found that as the length of time awake increased, performance decreased, especially for speed and accuracy of reaction times, dual task performance, recall capabilities and passive vigilance test accuracy. A performance equivalent to a 0.05% BAC occurred after subjects were awake an average of just 16.9 hours (+/- 1.8 hours in a 95% confidence interval] even though these subjects had just had a restful seven-hour sleep. A performance equivalent to a 0.10% BAC occurred after subjects were awake 18.8 hours (+/- 2.1 hours in a 95% confidence interval) following a similarly restful sleep.

Research studies in aviation, oil & gas and medicine [5, 6, 7] have found that cognitive fatigue is the primary root cause of human errors that cause personal injuries, near misses and fatal accidents in all types of cognitive or knowledge work.

No nuclear power plant licensee would ever let a legally-drunk or even mildly-intoxicated reactor operator into the control room. Yet a survey by the author has found evidence of poor sleep patterns in the nuclear industry [8]. Sleep diary and survey data from 1050 U.S. nuclear workers indicate that employees in normal operating conditions who work fixed night shifts average 5.75 hours of only fair to poor quality of sleep per day, while employees who work rotating shifts average 6.0 hours of fair quality sleep per day (+/- 2.98% in a 95% confidence interval).

This brain fatigue is the weak link in nuclear industry performance, safety and security. And, while the human brain cannot be re-engineered (yet), the culture and organization of work in nuclear power plants can be. For this reason, it is crucial that industry leaders re-think and re-engineer the cultural and organizational context in which cognitive processing tasks have to be performed in nuclear power plants across the globe.

Company issues

Many people in industry leadership currently believe that the root cause of fatigue risks is primarily employee lifestyle choices. Employees who "burn the candle at both ends" and fail to use the rest time available to them are considered to be the root of the problem. But there are two even more deeply-rooted causes of workplace fatigue that have to be addressed by the global nuclear industry if fatigue risk mitigation is to begin in earnest. One of these causal factors is linked to the business side of the nuclear power industry, and the other is linked to the cultural side of the industry.

In an effort to curb labour costs, financial managers have created a vicious circle in many nuclear generating plants. Most have hired only the base head count needed to cover the recognized posts across the 24/7 hours of operation. Rarely have they planned enough human capacity to cover employee absences, turnover, or special project assignments. As a result, there frequently are not enough qualified workers at the plants to prevent high overtime levels. In turn, the more overtime hours worked by the current labour pool, the higher will be the resulting sickness absences and staff turnover. Their absence will further increase the overtime and sleep deprivation levels for the remaining workforce. In future, the potential hidden costs of the base-labour staffing model have to be factored into the equation.

Another deeply-rooted cause of cognitive fatigue can be found in the organizational culture of many operating nuclear plants.

Many plant industry leaders come out of their countries' armed forces, and have brought with them the machismo culture of the military. Like surgeons who were trained to operate on little to no sleep, such leaders believe it is both possible and desirable—a sign of real toughness and a point of pride—to be able to function on as little sleep as possible. The problem with this macho mindset, and the cultural infusion that occurs when leaders' beliefs become common organizational practices, is that this mindset is flawed. Just because you survived one night or 1000 nights with little or no sleep, and managed to complete your tasks the next day, does not mean that your work was error-free. Humans cannot accurately judge their own performance, and all too easily reinforce their own sense of infallibility. A recent medical study [9] found that senior surgeons who performed operations under conditions of moderate to severe sleep deprivation (less than six hours of sleep time opportunity in 24 hours) faced an 83% increased risk of complications. It also found that general surgeons who performed elective surgery the day after working the previous night had a 171% higher risk of serious complications.

Like these senior surgeons, many nuclear plant leaders are modeling the "little-sleep-is-OK" approach to handling time pressures at work. They are driving a culture of foregoing restorative sleep in favour of urgent execution of critical job tasks, without understanding the real physiological limitations of the human brain. The belief in personal infallibility and the resulting culture that pervades many nuclear plants needs to be replaced with a true, fatigue-free safety and security culture, before behavioural changes will follow. And such culture change has to begin with leadership education on the root causes of workplace fatigue risks.

In a competitive marketplace for electric power generation, there are multiple strategic business reasons to establish comprehensive FRMS. They include sound risk management practice, prevention of rise in anti-nuclear sentiment (nothing terrifies a shaky public more than media images of sleeping nuclear workers on the job), improved KPIs, and improved profitability.

There are two pathways to fatigue risk mitigation in the nuclear industry: legal requirements and self-regulation. In 2008, the U.S. Nuclear Regulatory Commission (NRC) issued 10 CFR 26 Subpart I, to which U.S. reactor licensees had to comply by October 2009. According to the so-called Fatigue Rule, licensees need to establish fatigue risk management policies and procedures that adhere to seven primary regulatory requirements:

- clear identification of covered workers
- the maximum number of average weekly work hours per individual worker per shift cycle
- the minimum number of hours off between work periods and within every rolling 9-day period
- the process for self-declaration of fatigue
- the conditions and process for conducting individual fatigue assessments
- training for individual fatigue management
- the recordkeeping and reporting of work-hour control waivers in both online and outage conditions.

This set of regulations is in the process of being amended to allow for an average of 54 hours of work per covered individual per week across a rolling shift cycle no longer than six weeks.

Components of a Strategic FRMS

The regulations have provided a one-size-fits-all approach to fatigue risk mitigation. And although their intention of creating sufficient opportunities for unrestricted sleep and their requirement for employee training intervention are necessary steps in the right direction, I believe they do not go far enough. A comprehensive fatigue risk mitigation system (FRMS) addresses the root causes of workplace fatigue. Such a system should be strategically-aligned, culturally-driven, scientifically-sound, data-informed, risk-focused, performance-based and, most importantly, integrated into the operational fabric of a plant.

The FRMS should cover, at a minimum, the climate, structures, processes, policies and practices that govern both regular employees and on-site contractors involved in process safety-significant actions or making process safety-significant decisions. The system should touch on:

- Organization/work culture
- Physical work environment
- Staffing design/headcount model
- Work system model & job/task design
- Workload variability across normal conditions, planned outages and unplanned events
- Work hours & work/shift schedules, including outage schedules
- Individual fatigue risk assessments, including incident/near miss investigations
- Target metrics and periodic audits/reviews
- Continuous improvement process.

Only a systems-thinking approach will lead to the successful design and implementation of a fatigue risk mitigation programme. ■

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References

[1] Lombardi, D. et al. Daily sleep, weekly working hours, and risk of work-related injury or incident. Paper delivered at ICOH 19th International Symposium on Shiftwork and Working Time, Venice, 2009

[2] Dawson, D. & Reid, K. Fatigue, alcohol and performance impairment. Nature , 1997, 388:235

[3] Arendt, T. et al. Neurobehavioral performance of residents after heavy night call vs. after alcohol ingestion. Journal of American Medical Association (JAMA), 2005, 294(9): 1025-1033

[4] Williamson, A.M. & Feyer, A.M. Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication. Occupational and Environmental Medicine 2000, 57: 649-655.

[5] Broadribb, M.P. Lessons from Texas City: A case history. Institution of Chemical Engineers, Loss Prevention Bulletin 192, 2006

[6] Belenky, G. Fatigue model applied to fatal commuter air crash. Accident Analysis & Prevention, January 2011

[7] Sibenga, E.M. & Wu, A.W., Clinician mindfulness and patient safety. Journal of American Medical Association, 2010, 304 (22): 2532-2533

[8] Koen, S.L. Fatigue risks: myth or reality in U.S. nuclear industry? Paper delivered at ICOH peer-review forum, 19th International Symposium on Shiftwork and Working Time, Venice, 2009

[9] Rothschild, J.M. et al., Risks of complications by attending physicians after performing nighttime procedures. Journal of American Medical Association (JAMA), 2009, 302(14): 1565-1572