CASE STUDY: WHAT THE RESOURCES INDUSTRY CAN LEARN FROM THE AUSTRALIAN PIPELINE INDUSTRY'S FIGHT AGAINST FATIGUE?

As an industry that predominantly operates in harsh, remote areas and is serviced by fly-in/fly-out workers, there is little doubt that the Australian Pipeline Industry is one that is highly susceptible to fatigue and the risk that it brings.

In 2011, the Australian Pipelines and Gas Association (APGA - formally the Pipeline Industry Association) started out on a journey with TMS Consulting to address fatigue and lead the industry to best practice in fatigue risk management.

This journey began with a comprehensive Fatigue Management Study (FMS) on the industry. The aim of the study was to quantify fatigue and its risk factors and to profile related general health and safety factors. This was accomplished over a year by embedding a researcher onsite on a large-scale fly-in/fly-out pipeline construction project in Queensland.

The project required collecting detailed data from over 400 people using surveys, reaction time devices, sleep measuring devices, urine hydration analyses, and body measurements. Biomathematical fatigue modelling software was also used to assess work rosters, and data from OHS incident and near-miss reports and in-vehicle monitoring systems to reveal fatigue-related trends. This data, combined with industry feedback, then served as a basis for providing recommendations and areas of focus to aid effective fatigue management.

Following the release of the study in 2013, APGA then called upon TMS to develop industry guidelines and a practical toolkit to highlight the risks of fatigue and assist member companies to implement their own Fatigue Risk Management Systems. The guidelines and toolkit were released in October 2014.

This paper will provide a case study of TMS's work with APGA, detailing the findings of the study and the makeup of guidelines. This paper will also touch on what the resource industry can learn from the Australian Pipeline Industry and its commitment to protecting their workers against the deadly risk of fatigue.

ACKNOWLEDGEMENTS
TMS Consulting would like to thank the Australian Pipeline and Gas Association for their continued support and funding to ensure the industry-funded fatigue study could be undertaken.

TMS Consulting would also like to thank the member company for supporting the study on their project and all study participants who made this study possible.

Statistical assistance and advice for study data was provided by Dr Janine Beck, statistician, from Statisticat and Queensland University of Technology.

Review and advice on protocol design, data findings, and draft and final manuscript was provided by Dr Lee Di Milia, Professor of School of Management & Marketing at Central Queensland University.

INTRODUCTION
Excessive fatigue and its associated impairments can result in dire consequences. The grounding of the Exxon Valdez tanker, the sinking of the Estonia ferry, the Three Mile Island and Chernobyl power plant incidents, and the Rhine chemical spillage all had fatigue and/or human error attributed as causal factors (Dinges, 1995). Statistics from Australian road transport are no less confronting; estimates from 2007 identified fatigue as a significant contributor in around 20% of major vehicle accidents (Driscoll, 2009).

The Australian Pipeline industry is a safe industry. Some estimates suggest that safety incident rates in the Australian Pipeline industry are about an order of magnitude lower than in many overseas locations (Tuft & Bonar, 2009). This commendable achievement is reflected in the Australian Pipelines and Gas Association's (APGA) and member companies' commitment to ensuring safety. The industry developed AS2885 Australian Pipeline Standard and research by the Energy Pipelines CRC (EPCRC), which was established in 2009, continues to expand the industry association's Research and Standard Committee's work. However, as noted by Hayes, Tuft and Hopkins (n.d.) of the EPCRC, the Pipeline industry has typically focused on technical issues of pipelines without the commensurate focus on the organisational causes of incidents. An extension of this therefore is the nature of psychosocial and biological contributors to safety incidents, such as fatigue.

When the study began, very little published evidence existed relating to the extent of occupational fatigue present in the Australian pipeline industry. This is a critical knowledge gap given the often difficult working conditions encountered in large-scale pipeline construction projects. These conditions can include extreme environmental heat, dehydration, large and mobile plant equipment, uneven and unstable terrain, long distance driving, poisonous fauna and extended shift work schedules. As with the mining industry, many pipeline construction projects are notable for their long shift work schedules with some extending up to 28 continuous 10-hour work days and often in remote locations.

In 2010, TMS Consulting conducted a desktop work cycle review on the Australian Pipeline industry focussing on a large-scale coal seam gas pipeline construction project. This review involved an extensive review of the scientific literature in the areas of roster design, fatigue, sleep, and work-life balance. The review concluded that limited evidence existed on the links between work schedule length, fatigue and the frequency and severity of injuries, and incidents specifically within the Australian pipeline industry (TMS Consulting, 2010).

Based on research from other industries with similar working conditions and work schedules (such as fly-in/fly-out and drive-in/drive-out Mining, off-shore Oil and Gas), the 2010 review concluded that underlying levels of fatigue, such as those expected in most extended hours working schedules, need to be effectively managed with proactive fatigue management policies (TMS Consulting, 2010). It also identified serious gaps in the knowledge-base of fatigue, sleep, health, and safety profiles within the Australian Pipeline industry. In the review paper, TMS recommended a future research project to address these knowledge gaps. This recommendation was accepted by APGA, who commissioned TMS to conduct the study through a Fatigue Management Study (FMS).

The primary goal of the FMS was to quantify sleep and fatigue, and variables relating to health and safety using a single, large-scale coal seam gas pipeline construction project in the Queensland Surat Basin as a "representative" Australian pipeline construction project. Quantifying the extent of fatigue and fatigue risk factors in the Pipeline industry will help to identify key risk areas and aid the development of industry-specific fatigue management guidance. This project also provided a range of suggested recommendations and areas of focus to aid the industry in improving fatigue management policies, and subsequently improving safety. These recommendations were based on the findings of the FMS, discussions with key stakeholders and industry professionals, and on existing guidelines and research from comparable industries.

This study was designed to collect detailed information from a single pipeline construction project to determine the degree of fatigue that is present in operations within the Australian Pipeline industry, with a view to the development of effective fatigue management strategies. Thus, the primary aims of the study were to:

- Determine the extent of occupational fatigue
- Determine the prevalence of risk factors relating to fatigue, sleeping disorders, and poor health
- Provide guidance to APGA and the industry to aid the effective identification and management of fatigue in the Australian pipeline industry.

METHOD

The research methodology in this project was divided into two phases. *Phase 1* was designed to test three cohorts of volunteers twice daily (pre- and post-shift) on each day of the 28-day work cycle. *Phase 2* consisted of a generalised questionnaire which was distributed across multiple work sites on the same project. Testing was conducted at a single work site camp ('on-site') on a large-scale gas transmission pipeline construction project in a remote Queensland location. Each work roster ('cycle') is made up of 28 continuous on-site days (10 hour daily shifts) and nine rostered days off. Testing was conducted in two separate phases.

Participants

Phase 1

A total of 143 participants out of approximately 500 (28.7% of total) employees at camp volunteered for Phase 1. Participants were asked to self-select their primary area of work to facilitate comparison between occupation groups. These occupation groups were ‘field’ (including labourers, welders, riggers, and other tradespeople), ‘driver’ (including general vehicle drivers, truck drivers, and mobile plant operators) and ‘office’ groups (including management, administrators and safety advisors). After accounting for participant drop-outs, there were 65 participants in the field group (53% of total), 28 participants in the driver group (23% of total), and 30 participants in the office group (24% of total).

Phase 2

The Generalised Questionnaire (GQ) for Phase 2 was printed in large numbers (1000 copies) in order to reach as many members of the project workforce as possible (which was at the time approximately 1000 employees across the entire project). From 1000 distributed surveys, 417 were completed and returned (41.7% return rate); 230 of these were from field group (55% of total), 117 from driver group (28% of total), and 70 from office group (17% of total).

Measurements

Phase 1

Baseline Questionnaire (BQ): Baseline data was collected from all participants using a custom questionnaire prior to initial testing. The BQ included questions relating to gender, height and weight (for calculation of Body Mass Index, BMI), marital status and number of children at home. Health-related questions were also included such as blood pressure, usual alcohol and coffee/caffeinated beverage intake, sleeping patterns on- and off-site, self-reported medical history (e.g. previous or current health conditions), occupational history and self-rated safety perceptions. In addition a host of other surveys were used detailing sleep apnoea risk factors, subchronic/chronic occupational fatigue, hydration knowledge, sleep hygiene practices and burnout.

Daily questionnaires:

These forms were completed by participants prior to and following each daily work shift in a dedicated room (*Figure 1*) and asked participants to report on the following:

- Caffeine intake prior to questionnaire
- Alcoholic beverage intake on the previous day
- Minutes of exercise performed on the previous day
- Sleeping patterns (see diaries and actigraphs)
- Subjective sleepiness (Karolinska Sleepiness Scale, KSS, sleep quality, SQ; Åkerstedt, 1990), and fatigue (Samn-Perelli Fatigue Scale, SPC; Samn & Perelli, 1982)
- Objective neurocognitive performance (5-min Walter Reed Psychometric Vigilance Task, PVT; Thorne et al., 2005).

The post-shift (i.e. afternoon) questionnaire asked participants to report on the following:

- Caffeine intake prior to questionnaire
- Start time of shift that morning
- Total hours of work that day
- Subjective sleepiness and fatigue
- Objective neurocognitive performance.

Phase 2

Generalised Questionnaire (GQ):

This item is a three page questionnaire designed to evaluate a range of topics. These include:

- Demographics
- Lifestyle
- Basic health and medical history
- Sleep apnoea screening (Multivariate Apnea Prediction Index; Maislin et al., 1995)
- Sleep/wake cycles
- Acute assessment of fatigue on-site and off-site (SPC scale; Samn & Perelli, 1982)
- Chronic/sub-chronic assessment of fatigue (FAS; Winwood & Wineheld, 2005)
- Hydration and sleep hygiene knowledge (H2O-Q & SHI).

RESULTS

Phase 1 Results

Phase 1 demographic results are displayed in *Table 1*.

Table 1. Phase 1 and 2 results

Phase 1	Occupation Group					
	Field		Driver		Office	
Gender (% of group total)	Male	Female	Male	Female	Male	Female
	100	0	100	0	71.5	28.5
Age (years)	34.4 (SD 11.6)		37.8 (SD 9.9)		35.3 (SD 10.8)	
Body Mass Index (kg/m^2)	27.5 (SD 3.65)		30.1 (SD 3.9)		27.7 (SD 6.3)	
Pipeline experience (years)	2.3 (SD 2.6)		3.6 (SD 5.6)		3.2 (3.8)	
Units of alcohol on-site per day	3.2 (SD 1.7)		4 (SD 1.5)		3.1 (SD 1.7)	
Number of daily cigarettes on-site	5.5 (SD 9.6)		8.8 (SD 10.5)		2.8 (SD 5.7)	
Average Sleep Duration (hours)	6.4 (SD1.1)		6.2 (SD 0.95)		6.5 (SD 1.1)	
Phase 2	**Occupation Group**					
	Field		Driver		Office	
Age (years)	35 (SD 10.5)		40.1 (SD 10.7)		37.3 (SD 10.3)	
Body Mass Index (kg/m^2)	27.6 (SD 3.7)		30.5 (SD 5.6)		27.9 (SD 5.8)	
Pipeline experience (years)	6.5 (SD 9.2)		3.4 (SD 4.9)		4 (4.5)	
Obese Classification (% of group total)	31.9		50.9		27.1	
Units of alcohol on-site per day	10.9 (SD 14.8)		9.6 (SD 12.7)		6.6 (13.7)	

Number of daily cigarettes on-site	17.9 (SD 10.4)	17.3 (SD 8.8)	12.7 (SD 6.8)
Average Sleep Duration (hours)	6.9 (SD 0.9)	7.1 (SD 0.9)	6.7 (SD 1)
High Risk of Sleep Apnoea (% of group total)	18.9	36.2	23.8

Performance Measures
Only limited changes were found between pre- and post-shift scores on the 1/RT, raw RT and lapse variables. That is, the daily work shift had little discernible impact on these performance measures when each shift was viewed in isolation. A gradual and consistent reduction in 1/RT performance occurred over the work cycle, with the greatest change occurring approximately between days 8 and 20. Significant changes in mean reaction time ($p<.01$) were observed over the work cycle, with a gradual worsening of performance between baseline on day 1 and day 28.

Subjective Measures
In general, inconsistent changes were observed over the work cycle relating to differences in pre- and post-shift subjective sleepiness and fatigue ratings. On both scales a gradual increase occurred over the work cycle but these changes are of a limited magnitude.

Phase 2 Results
Demographic information for *Phase 2* can be found in *Table 1*. Not noted in the table, although the overall average pipeline experience was 4.4 across the whole sample, 47% had less than 1 year of pipeline experience.

Work Scheduling Characteristics
Mean rostered working hours were similar between occupation groups, with a pooled weekly average of 69.4 hours (SD 6.6 hours) and no significant group differences. This figure aligns with the project’s official roster which is generally set at 70 hours per week. Yet for actual hours that are worked per week, the field group work 80 hours (SD 10.3 hours), the driver group 78.4 hours (SD 9 hours), and the office group 82.6 hours (SD 9.7 hours), again with no significant group differences. On this project, approximately 56% of all participants commuted to and from the camp site using their own transport (mean travel time = 8.1 hours, SD 5 hours) instead of using company-provided transport.

Degree of Subjective Fatigue
Participants were asked to rate (on the Samn-Perelli fatigue scale) their general level of fatigue/ exhaustion following the cessation of a full work cycle. For field, ‘Extremely tired’ was the most reported feeling (22.2%) following the cessation of a work cycle, with ‘Moderately tired’ second (18.2%). For the driver group, the most reported feeling was ‘Okay’ (30.9%), with ‘A little tired’ second at 20.2%. In the office group, ‘Extremely tired’ and ‘Moderately tired’ were approximately equal at 20.5%.

Perceptions of Fatigue and Safety
On average, it was found that the office group required the least amount of nightly sleep to work safely (7.1 hours, SD 1 hours), compared to field and driver groups (7.5 hours, SD 0.9-1 hours). The average duration of objectively (actigraphs in Phase 1 main study) and subjectively (self-reported) assessed hours of sleep are considerably less than the perceived

amount of sleep needed to work safely. Stated another way, people are sleeping less than they believe they require. The majority (76%) of respondents believed that unsafe levels of fatigue are common in the industry, with drivers on average perceiving the risk to be lower.

OHS Incidents

OHS incident and near-miss data from this project over a period of six months was made available for analysis. Results for incident and near-miss trends over the work day showed a marked increase between 8 and 12 hours into the work shift, with this period accounting for 49% of all daily incidents. Heightened rates of incidents are also notable for less than 4 hours into the work shift. The hours between 4 to 8 and over 12 hours had the least absolute percentage of reported incidents although a higher probability of incidents in the >12 shifts may exist based on relative analyses.

Results Summary

The data in this study suggested that consistent and statistically significant impairments in neurocognitive performance occur over the 28-day work cycle in this sample of Australian pipeline construction employees. This performance decrement showed little evidence of stabilisation.

Other potential risk factors were also identified. These include consistently short nightly sleep durations; an elevated probability of sleep apnoea in drivers; long working hours; long commutes home following the cessation of a work cycle and also potentially during the early morning hours; and a pronounced peak of safety incidents between 8 to 12 hours on shift. A summary of results from both phases of the study is represented in Figure 1.

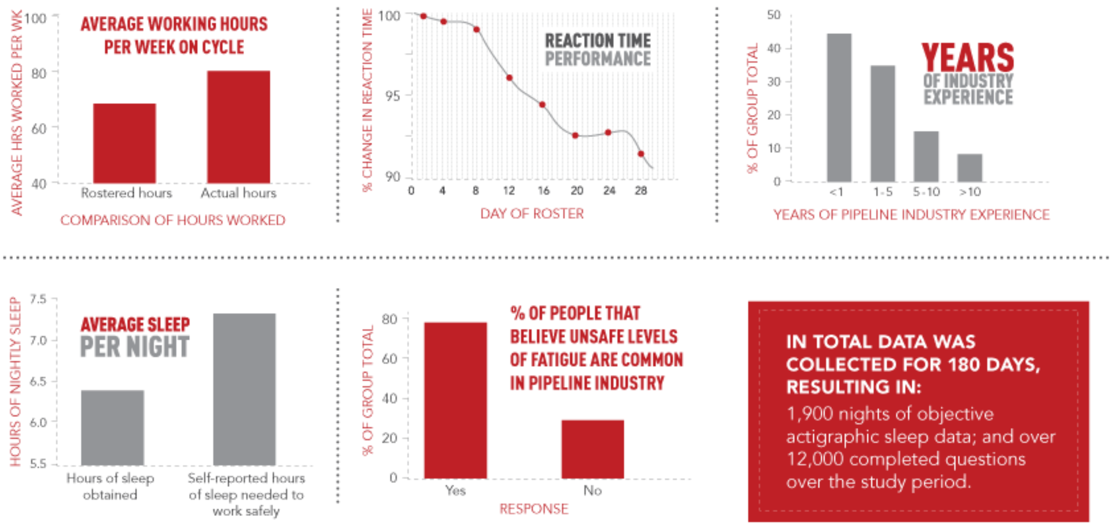

Figure 1. *Summary of Results*

DISCUSSION

Occupational fatigue is thought to exist in most extended shift schedule FIFO environments. This project evaluated fatigue in a large-scale coal seam gas pipeline construction project in remote Queensland. A number of fatigue risk factors, and health and safety information were collected and evaluated. Given the increasing number of coal seam gas pipeline construction projects around Australia, research addressing the status of fatigue, health and safety in this industry is an important step in ensuring safe and effective future growth. This is particularly important given the working conditions that are often present in these projects, including extended working hours, camp-based accommodation, high ambient temperatures and the lack of specific research pertaining to Australian pipeline operations. Moreover, the highly mobile nature of the pipeline workforces demands an examination of potential risk exposure to individuals, companies, and the community more broadly.

Several indicators in this study suggest the typical work schedules and work environments in the industry may carry a high level of risk for companies and employees. Probable risk factors for excess fatigue, sleep disturbances and disorders, impaired health, and possible adverse impacts on safety were observed. In particular, risk factors such as extended daily work hours, sleeping disturbances and early rise times may explain the increased lapses and slower reaction times.

Employees also self-reported tiredness and the need for additional sleep in order to work safely. One of the most compelling pieces of evidence for excessive accumulated fatigue is reflected by performance decrements (see Figure one for reaction time performance); whereby pre- and post-shift 1/RT measurements for each group have been collapsed into pooled single daily averages for several time points over the work cycle. These findings suggest that in general, across the entire sample, steady declines in neurocognitive performance occur and with little evidence of stabilisation. When looking at percentage change of 1/RT performance over the work cycle, the decrement in neurocognitive performance seen in the FMS is similar in magnitude to performance decrements obtained at 0.05% alcohol intoxication.

An assessment of sleep/wake profiles discovered that on average most of this sample obtained around 6.2 to 6.5 hours of sleep per night. Approximately 34% of participants obtained less than 6 hours of sleep on any given night. In conjunction, it appears that a reasonable probability of sleep apnoea is present in this sample. This risk is focused particularly around the driving group who on average obtain the least sleep, and who generally have the highest rate of risk factors for sleep apnoea. The protection of quality sleep opportunity is of paramount importance in working environments such as these.

Another potential risk factor identified in this study is the extended working hours prevalent in this sample (>80 hours a week); hours that are of a long and monotonous nature for drivers. This point is considered in light of the possibility that the long working hours may simply be an artefact of this particular pipeline construction project, as with any of the other findings.

A significant percentage of this sample commute to and from the work site using their own transport which is on average a long commute (approximately 5-8 hours each way), and may involve considerable time in the high risk times for driving in the early morning hours. This may be an important area of risk for companies to identify and mitigate.

Finally, a pronounced peak in OHS incident and near-miss events were evident between 8 and 12 hours on-shift. While this is not evidence of fatigue or fatigue-related events, it does align with predictions regarding when fatigue would be at a relative peak during the working shift and suggests that this period of the shift may be higher risk and therefore should be subject to close review in the company safety management approaches.

Limitations

Like any field-based study, limitations were present in this study and must be acknowledged (see full list of limitations at www.tmsconsulting.com.au/fms). The following is a summary of some of the identified limitations that need to be read in conjunction with the outcomes:

- Small sample size that was taken from a single project
- Possible selection bias of participants such that less fatigued, or conversely more fatigued people, may have been more likely to take part in testing. This indeterminable factor could result in an underestimation or overestimation of fatigue impairment
- Field-based measurement may have lacked sensitivity for measuring reaction time and sleep
- Inability to review long-term and detailed data on workforce burnout and stress
- Limited ability to evaluate health and safety incident and near-miss information
- Inability to determine if there is corroborating evidence linking fatigue impairment to increased safety incidents or driving risk.

Industry Lessons

This case study provides many lessons for both the pipeline industry and other industries such as mining and transport. The following tips for success when managing fatigue are recommended:

For industry:

- Engage an industry wide approach that allows everyone to participate and collaborate
- Assess the industry's cultural maturity and align strategies to the findings – aim for a progressive shift rather than significant leap in maturity
- Consult industry members and seek buy-in to initiatives
- Provide practical tools that can be tailored to any organisation.

For organisations:

- Engage management and leaders as well as health and safety staff
- Create a culture of self-reporting and acknowledge fatigue initiatives
- Use field and team based coaching rather than enforcement to drive change
- Set targets and rewards (lead) rather than problems and punitive (lag)
- Encourage teams to self-monitor performance.

More generally, the following are lessons learnt from the FMS:

- Passionate senior people drive change
- External assessment of fatigue risk alleviates suspicion about 'the company's intentions'
- There are a lot of myths about fatigue and sleep that need to be busted at the employee level
- Raising awareness is key to getting traction and change
- Results and why they are relevant must be reported back to employees
- Fatigue should not be seen as separate from safety but another hazard to be mitigated.

Practical Outcomes of Research

In order to make the results of this research accessible to the wider industry, and convert research into practice, this research was used to inform and develop a Toolkit and set of Guidelines for APGA. The purpose of the guidelines and associated toolkit is to provide member organisations with practical guidance on how to identify and systematically manage fatigue in order to minimise the risk to health and safety so far as is reasonably practicable.
The intent of the guidelines and toolkit are to encourage the adoption of uniform fatigue management practices across the industry, providing advice on how to develop and implement a Fatigue Risk Management System with specific applicability to the pipeline industry. This handbook also addresses the cultural change elements required to adequately manage fatigue and safety in the industry.

The implementation of the guidelines and toolkit ensures that the Australian Pipeline industry is managing fatigue in a way that is informed by best-practice research, minimising the risk of fatigued on individuals and organisations.

In addition to the more formal documentation, there are also tools that can be picked up and used in any organisation, such as the Fatigue Management Infographic that can be displayed in organisations, shown in Figure 3. A video was also produced to be used as part of induction or training programs. The guidelines and accompanying tools can be found at apga.org.au.

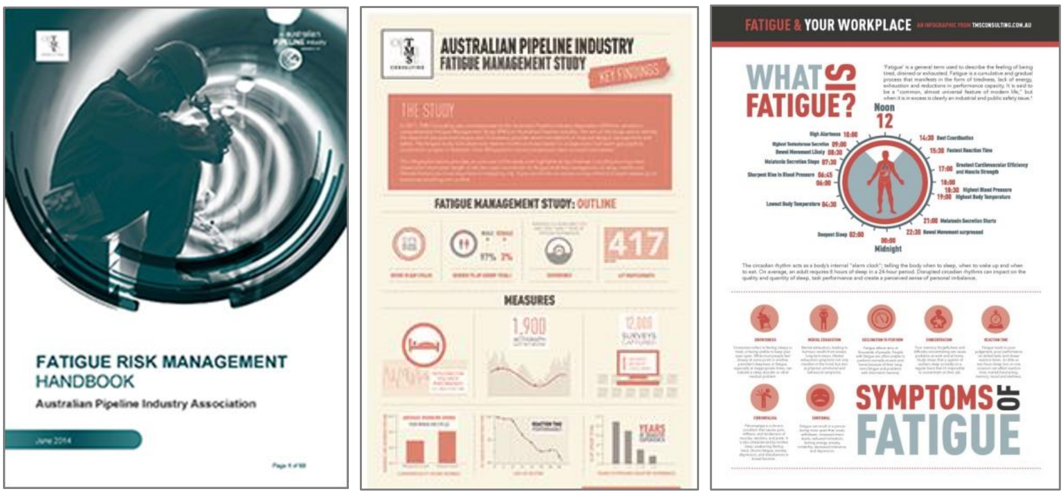

Figure 2. APGA Fatigue Management Toolkit

References

Åkerstedt, T. (1990). Subjective and objective sleepiness in the active individual. International Journal of Neuroscience, 52, 29-37.

Dinges, D.F. (1995). An overview of sleepiness and accidents. J Sleep Res., 4(S2), 4-14.

Driscoll, O. (2009). Major Accident Investigation Report 2009. National Centre for Truck Accident Research, National Transport Insurance. Retrieved January 29, 2013, from: http://www.nti.com.au/news-media/data/article_19.pdf

Hayes, J., Tuft, P., & Hopkins, A. (n.d.). Organisational Safety – A New Research Venture for the Australian Pipeline Industry. Energy Pipelines CRC. Retrieved May 17, 2013, from: http://www.epcrc.com.au/getdoc.php?doc=724bcd176008dff5

Maislin G, Pack AI, Kribbs NB, Schwartz PL, Schwartz AR, Kline LR, Schwab RJ, & Dinges DF (1995). A Survey Screen for Prediction of Apnea, Sleep, 18(3), 158-166.

TMS Consulting. (2010). Fatigue and its relationship to roster cycle length. Retrieved January 30, 2013, from: http://www.apia.net.au/wp-content/uploads/2011/11/Wood-Paper.pdf

Samn, S.W., & Perelli, L.P. (1982). Estimating aircrew fatigue: a technique with implications to airlift operations. Brooks AFB, TX: USAF. School of Aerospace Medicine; 1982. Technical Report No 1982, SAM-TR-82–21.

Thorne, D. R., Johnson, D. E., Redmond, D. P., Sing, H. C., Belenky, G., & Shapiro, J. M. (2005). The Walter Reed palm-held psychomotor vigilance test. *Behavior Research Methods, 37*(1), 111-118.

Tuft, P., & Bonar, C. (2009). Experience with the Australian Pipeline Incident Database, in APIA Convention. 2009: Cairns. Retrieved May 17, 2013, from: http://www.apia.net.au/

Winwood, P.C., Winefield, A.H., Dawson, D., & Lushington, K. (2005). Development and Validation of a Scale to Measure Work-Related Fatigue and Recovery: The Occupational Fatigue Exhaustion/Recovery scale (OFER). Journal of Occupational and Environmental Medicine, 47(6), 594-606.