

Contract Report

Operator Fatigue Through Nightshifts in Succession



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for Joint Coal Board Health & Safety Trust

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Technical Summary

The Joint Coal Board (Health & Safety Trust) funded ARRB Transport Research Ltd. to investigate fatigue and performance in open cut mines. The main questions were to assess:

- What is the most important contributor to acute fatigue in open cut mining? Is it length of shift (eg. 8 hours Vs 12 hours) or is it time of day (eg. circadian effects)?
- What is the limit of successive day or night shifts before chronic fatigue affects operator performance in open cut mines?
- What is the minimum amount of sleep required to perform adequately through a 12-hour day or night shift?
- Can we use an alcohol comparison to assess cut-off levels for fatigued operators?

This research proposal addresses the Joint Coal Board Health and Safety Trust's research priority on fatigue and stress.

The project methodology included utilising the ARRB Fatigue Monitoring Device in eight haul trucks, testing 24 subjects over several weeks. Operators worked a 14 night, 1 day off, 13 day roster of 12-hour shifts in a fly-in, fly-out operation with excellent opportunities for restorative sleep between shifts. A total of 3,500 hours of real-time data was collected. The fatigue monitor was also used in a driving simulator, where a further 14 subjects undertook alcohol and performance trials. A total of 28 hours of control data and 54 hours of experimental alcohol and performance data was captured for the study.

It can be argued that for a single night of driving haul trucks, there appears to be no affect on operator fatigue from the amount of time on task (for the 12 hours). The circadian influence had a stronger affect than working more than eight hours.

Of the fourteen nights worked at the site, nights thirteen, fourteen, seven and two respectively, were the worst. This presents a conundrum for policy makers who may like to place caps on working hours or rosters in the hope that it will alleviate the fatigue issue. It will not. The major finding within this study is the combined influence of circadian rhythms (human body clock) and individual variability. The lifestyle habits and the health of individuals have a profound effect on operator performance as shown by the strong positive correlation between high fatigue risk scores and poor performance. An individualistic approach would appear to have the best chance of reducing high potential incidents due to fatigue through successive nightshifts.

The ARRB Fatigue Monitoring Device has been shown to be very good at measuring reduced driver performance due to alcohol intoxication. The performance measures relating to high potential incidents within the study, are found at blood alcohol concentrations of 0.02%. This adds strong support for setting alcohol tolerance levels at 0.02% blood alcohol concentration for the mining industry, as the corresponding level of performance can be considerably poor for some drivers.

Similarly, if the ARRB Fatigue Monitoring Device technology is utilised within any mining situation, there is strong evidence that the parameters of poor performance measures equate to the performance of drivers with a blood alcohol concentration of between 0.02% BAC and 0.05% BAC.

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The findings of this research study are of significant importance to the mining industry. It is said to be the first real set of objective data presented to the Australian mining industry that has been captured from within the industry. It is a large amount of data (3,500 + hours), which lends itself to scientifically valid interpretation.

Recommendations

The findings clearly indicate that placing limits on successive nightshifts will not in itself alleviate the fatigue problems that are present during nightshift operations. In fact it could be argued that people may rely on limits to avoid the consequences of fatigue, rather than investigating other causal factors. The data collected from the fatigue monitoring devices, together with the fatigue risk scores and anecdotal evidence, create a strong case for arguing that each operator takes to work, health and lifestyle issues that impact on their subsequent performance. This is then compounded by circadian influences through the circadian trough (midnight to dawn), but may also manifest itself through other parts of the evening that are normally considered as 'high arousal' periods.

It would be wise to continue gathering such data at every opportunity to help in the continuing determination of ways to manage fatigue and performance. The current data has been obtained from a fly-in, fly-out site, whereby operators get adequate opportunity to obtain restorative sleep between shifts. Data needs to be captured from other sites that have nearby community living and fewer shifts for which to compare the data. This will assist to develop a more reasoned understanding of the number of successive nightshifts before performance begins to deteriorate below acceptable safety levels. Until such time, operators should be viewed as individuals and it should be accepted that their performance will vary from other operators and at different times of the day/night. This will not be managed by limits on operations.

Acknowledgments

The Joint Coal Board (Health & Safety Trust) are kindly acknowledged for their funding and support of this very important research. This research has made an important inroad into how the mining industry might best formulate fatigue management plans and strategies.

Many thanks go to Murdoch University's Assoc. Prof. Laurence Hartley who provided the driving simulator for alcohol testing purposes.

Kind acknowledgments are also forwarded to Sons of Gwalia and MacMahons who provided the site, haul trucks, operators and assistance throughout the trial. Finally, the 24 operators who put more than 3,500 hours into operating machinery with the ARRB FMD technology in place. It is hoped that they feel they contributed to a very important cause – their own!

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1 Introduction

At the 2001 Queensland Mining Industry Health and Safety Conference in Townsville, Australia, it became evident that fitness for duty and fatigue were subjects that commanded the attention of the delegates. However, all reports except one on fatigue in mining, were focussed upon subjective or anecdotal measures of fatigue with few suggestions for fatigue countermeasures. The one exception was the work conducted through ARRB Transport Research at the Western Australian Hamersley Iron open cut operation (Mabbott, 2001). It reported on objective measurements of performance and performance decrements throughout the shift, utilising a stimulus-reaction task and countermeasures that are being developed to avoid the consequences of fatigue. Whilst the report was focussed upon the practical utility of the fatigue monitor, it is now possible to utilise the device as a research tool.

Several recent road transport reports have argued unequivocally that driving at night contributes to the risk of fatigue-related impairment. An excerpt from the Mabbott and Newman (2001) report is reproduced below as an example.

The “Commercial Motor Vehicle Driver Fatigue and Alertness Study (Wylie, Shultz, Miller, Mitler & Mackie, 1996) in the USA and Canada is said to be the largest and most comprehensive driver fatigue study conducted in North America. Eighty drivers participated in around 4,000 hours of driving, utilising either 10 hour US regulated hours of service trips or 13 hour Canadian regulated hours of service trips. The findings of the study relevant to this project are summarised as:

- *That hours of driving was neither a strong, nor consistent predictor of fatigue as detected by video observations;*
- *Video records of comparable daytime segments of both 10 hour and 13 hour trips revealed no differences in observed fatigue of drivers;*
- *Video records of drowsiness observed from the driver’s face were greater during the night than during the day. The peak drowsiness period occurring between late evening and dawn;*
- *Midnight to dawn driving was associated with lower operator performance on four measurement criteria” (p. 6).*

This Driver Fatigue and Alertness Study concluded that “time of day was a far better predictor of decreased driving performance than time on task or cumulative number of trips”. Further to this, the authors also concluded that there are “no known Highway Transportation hours-of-service regulation in the world that address time of day effects” (Wylie et al., 1996).

The Mabbott and Newman (2001) report was directed at Australia’s prescribed hours of driving for commercial vehicles and discussed weighting night hours of operation heavier than daytime to reflect the increased risk of fatigue related crashes. Similarly, the Fatigue Expert Group recommended a reduction in night travel to a maximum of 18 hours of night work before two consecutive nights of sleep are taken (Fatigue Expert Group, 2001). The two above reports clearly indicate a strong position that states night driving is more fatiguing than day driving. However, to date there have been few attempts to measure performance decrements due to night driving in Australia.

Hanowski, Wierwille and Dingus (2003) instrumented trucks with video cameras to determine if drivers were becoming drowsy and whether that had an effect on critical incidents (loosely defined as '*an unexpected event resulting in a close call or requiring fast action on the part of a driver to avoid a crash*' , p. 157). The research showed that a small percent of the drivers (<25%) accounted for a large percent of critical incidents (>85%). Further, it was argued that drivers appeared to bring the fatigue experience with them to the job, rather than the job causing the fatigue. Anecdotal evidence suggests that this occurs in many occupations.

1.1 Real-Time Testing

Williamson, Feyer, Friswell and Finlay-Brown (2000a, b, c & d) undertook a range of experiments (ATSB Reports CR 189 – CR 192) to assess different driving regimes. In their first report (CR 189) Williamson et al (2000a) conducted a within subjects test that compared the performance effects of sleep deprivation to those of alcohol content ranging from 0% to 0.025% to 0.05% to 0.1% BAC. This was undertaken in a simulated environment using a range of tests to determine which tests were most sensitive to sleep deprivation and/or fatigue.

In their second report (CR 190) Williamson et al. (2000b) used the validated tests for evaluating alternative compliance schedules in the heavy transport industry to better manage fatigue. They chose two different work-rest schedules. The first was the current working hours regulations which were utilised as a baseline for comparison with the alternative schedule. Drivers who participated in the current working hours regulation schedule were able to be tested on road. The second schedule involved drivers on a simulator as they drove for longer hours than is actually permitted under the current working hours regulations. The results showed that the drivers adhering to the current working hours regulations schedule showed no changes in test results over the week. The results from the alternative schedule of much longer hours showed significant deterioration in fatigue and performance. The authors found that certain tests captured circadian effects of lowered performance at intervals during testing of extended schedules. They mention that some of the performance decrements would likely cause unsafe performance on the road.

The Williamson et al. (2000c) third report examines the pilot Fatigue Management Program in Queensland, under the Queensland Department of Transport Alternative Compliance Program. This work-rest schedule differs from the current working hours regulations in that it allows longer periods of work without rest and it allows the continuous rest of six hours to be taken in two periods. This study was conducted using the same methodology as their second report only they were looking at the influences of the different ways of scheduling. They found that the effectiveness of alternative work-rest schedules were doubtful. They also reported that levels of fatigue were not high at any stage of the experiment. However, reaction speed was significantly slower on the Simple Reaction Time Test, to the point that it was slower than the level found in drivers at 0.05% BAC. The authors also conducted a second examination of the current working hours regulations for managing fatigue. The results were the same as in the second study.

Williamson et al. (2000c) utilised several tests that captured the performance capacity of drivers and showed performance decrements through periods of fatigue and for alcohol consumption. The tests were administered before the trip commenced, at intervals during the trip, and after the trip was completed. As such, the authors were able to capture 'snapshots' of performance for

certain times of the study. This has allowed inferences to be made on schedules for performance and safety.

One of the issues raised in the Williamson et al. (2000d) studies was the need to test the drivers for performance during the trip itself. This is important as performance is reflected in brain activity and past research shows that spikes of theta waves reflects poorer performance (Khardi and Vallet, 1995). Research has shown that humans can, in times of drowsiness, pull together a certain amount of resources to achieve an endpoint if thought necessary. For example, even sleep deprived subjects can perform tasks for up to 15 minutes in duration (Arnold & Hartley, 1998). Electroencephalograms (EEGs) have shown this to be caused by shifts in brain waves. For example, Khardi and Vallet (1995) noticed alpha and beta brainwave activity through normal operating conditions, then shifting to alpha and theta activity. The shift coincided with impaired driving. What this means in simple terms is that when a driver is feeling tired, they might become alert after a while, become drowsy again, become alert again, and so on. As such, performance decrements reflecting theta activity will only be measured by chance if measured (for example) every two hours. This intermittent intervention (for example, the Personal Vigilance Test or other psychological vigilance or reaction tests) as well as possibly missing performance decrements may bias the results by impacting on the drivers' normal driving routine. Therefore, a device capable of measuring the performance of drivers in real-time is required to gain a better understanding of performance throughout the whole task period.

In 1999, ARRB Transport Research Ltd. (ARRB TR) were commissioned by the Australian Coal Association Research Program (ACARP) to conduct a review of local and international technology that would be useful for monitoring heavy vehicle operator fatigue in open cut coal mines. The report (Mabbott, Lydon, Hartley & Arnold, 1999) described several devices that were examined for their implementation into open cut coal mines. Similar research was later conducted for the long distance heavy transport industry for the National Road Transport Commission (Hartley, Horberry, Mabbott & Krueger, 2000). Both reports noted the lack of practical devices available for implementation into environments utilising heavy vehicles in rugged terrain or for long distance operators. ARRB TR has since developed a device that is specifically designed to monitor the performance of heavy vehicle operators, which as a result of this work will be invaluable to this project. It has the capacity to monitor operators in real time and constantly measure the performance and decrements in performance due to fatigue or other impairment.

1.2 Time of Day Effects Shown in Recent Testing

Time of day effects are arguably one of the best predictors of shift worker performance. A considerable number of studies have shown this to be most prominent between midnight and 6 AM and between lunchtime and 5 PM (eg. Wylie et al., 1996; Folkard, 1997). Figure 1 plots the frequency of times that operators have responded slowly to the stimuli in the recent trial in an open cut mine. The data represents over 200 hours of real-time testing with truck operators working 12.5 hour day and night shifts. As can be seen, a circadian pattern is clearly evident in the data which reflects both slow and extremely slow responses.

In this particular mine there appears to be a fatigue issue between 11am and lunch time. Although this is slightly earlier than circadian influences would suggest, there has been two fatigue related crashes during this time prior to the trial.

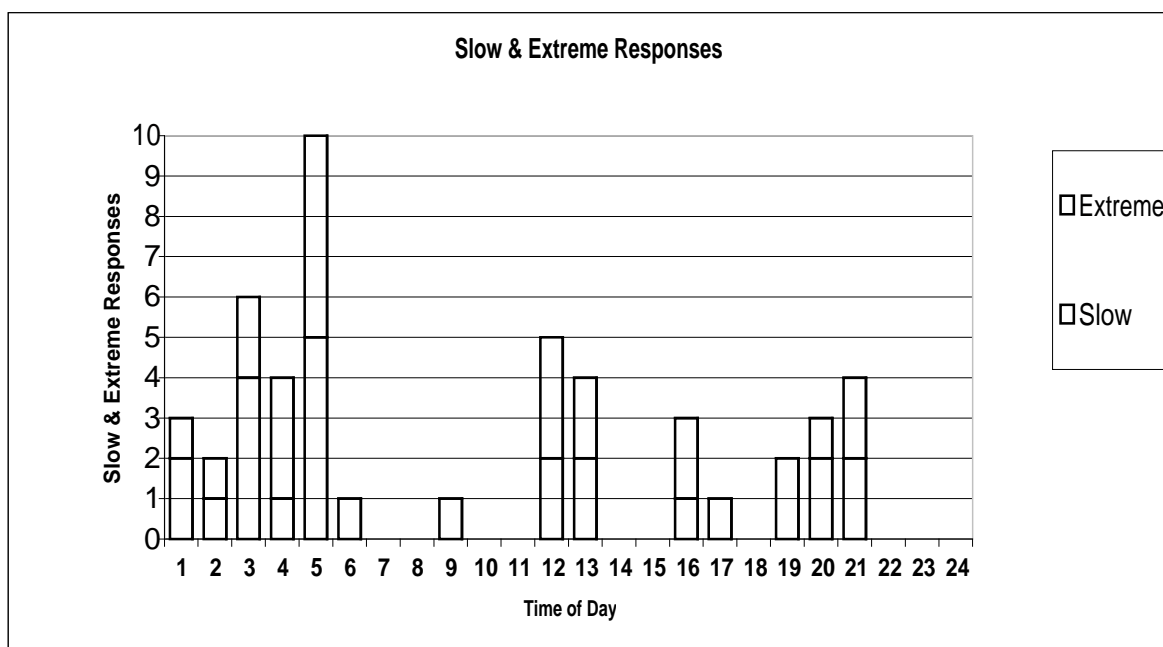


Figure 1: Time of day performance decrements from 12.5 hour driving shifts

Table 1 shows the performance decrements for four, six-hour time periods throughout the 24-hour day. Once again, the results are highly reflective of other time of day performance studies. Specifically, the fatigue monitor has assessed slow performance on the reaction task more between midnight and 6 AM than for any other time through the 24-hour day.

Table 1: Percentage of slow responses showing lowered performance

	6 PM to Midnight	Midnight to 6 AM	6 AM to Midday	Midday to 6 PM
Slow Responses	18.4%	53.1%	12.2%	16.3%
	Nighttime		Daytime	
	71.5%		28.5%	

2 Project Objectives

This research addresses the Joint Coal Board Health and Safety Trust's research priority on fatigue and stress.

It is proposed that the following research questions be asked within the study:

- What is the most important contributor to acute fatigue in open cut mining? Is it length of shift (eg. 8 hours Vs 12 hours) or is it time of day (eg. circadian effects)?
- What is the limit of successive day or night shifts before chronic fatigue affects operator performance in open cut mines?

- What is the minimum amount of sleep required to perform adequately through a 12-hour day or night shift?
- Can we use an alcohol comparison to assess cut-off levels for fatigued operators?

An alcohol comparison option is utilised to enhance the face validity of the data produced while testing drivers during day and night driving operations. Similar to findings produced by Williamson et al. (2000c), this study will attempt to identify if reduced performance due to alcohol intoxication is picked up by the FMD. Further, if the performance of intoxicated individuals can be likened to levels of fatigue in any way.

3 Project Methodology

The ARRB FMD was utilised to test truck operator's performance driving under successive night and day shifts. Drivers were tested driving throughout their working shifts in real-time. The method builds upon the recent work undertaken at the Hamersley Iron Mine operation in North-West Western Australia. This will be shown in Methodology 1. The ARRB FMD was also utilised to test subjects driving in a driving simulator whilst becoming intoxicated with alcohol. This will be shown in Methodology 2.

3.1 Methodology 1 – Nightshifts in Succession

3.1.1 Subjects

A total of 24 volunteers were engaged in driving dump trucks fitted with ARRB Fatigue Monitoring Devices (FMD). There were 17 males and 7 females within the study. Ages ranged from 24 to 60 years old. Subjects were at a 'fly in fly out' operation that had very adequate sleeping arrangements within its camp.

3.1.2 Apparatus

The recently developed "Fatigue Risk Questionnaire" (Mabbott 2003, unpublished) was administered to all participants within the study at the minesite. The pen and paper test is self-administered and attempts to capture a snapshot of the health and lifestyle of the individual. Scores are given for each item regarding the item's likely influence on operator performance. The tool assists in the identification of obesity, poor diet, poor sleeping habits and possible sleep disorders. A small booklet was also given to each operator in which to record a sleep diary so the amounts of sleep could be correlated with work performance.

The ARRB FMD was utilised as a measure of operator performance throughout the research study. It was developed as an early warning system of reduced operator performance. It is a forced-choice reaction device that requests a reaction to both an audible and visual stimulus. In its current operation in open cut mine dump trucks, the reaction is made by pressing a left or right button in response to a left or right stimulus light arrow. All subjects were instructed on its use and briefed as to when the device should be turned off (eg. device can be turned off if driving conditions become hazardous – heavy rain, fog, etc). The ARRB FMD has the advantage of using both audible and visual stimuli to assess reaction time through a forced-choice task, during real time testing and under the operators normal safe driving conditions.

Eight Caterpillar C777 rear dump trucks were fitted with FMDs, which represented two-thirds of the mine's truck fleet. The devices were hard-wired into the trucks and had electrical inputs for reverse and park brake so that the device would disable when in either of the two motions

(eg. parked for dumping or reversing). A radio communications system was installed so that the devices could forward data from the trucks to a central personal computer for storage and downloading. This was made possible with Maxon 1 watt radios within the vehicles and a yagi and dipole situated on a hill to transmit packets of data to the central PC, housed at the management centre. Radio transmission was covered over three pits within a 13 kilometre distance. Data was downloaded on a weekly basis for storing and analyses (interim and final).

3.1.2.1 Normal operation

The FMD stimulus-reaction device operates in four defined stages. Under normal circumstances (and the operator is wide awake) the device will present a light and audio stimulus every 7 to 10 minutes apart. If the operator reacts within one standard deviation of his/her personal baseline reaction time, nothing else will happen until another stimulus presentation occurs randomly within 7 to 10 minutes. Stimulus presentations are random left and right.

3.1.2.2 Slow or wrong responses

If the reaction to the light stimulus is slightly slower than normal (between 1 & 2 Standard Deviations), or if the wrong reaction button is pressed (eg. left stimulus light – right reaction button), the device will automatically reduce the period of time between stimulus presentations (stimulus interval period). The next presentation will occur within 4 to 6 minutes apart, based upon the notion that more testing should be carried out if the operator is getting tired.

3.1.2.3 Slower responses

If a reaction to the stimulus light is considerably slower (between 2 & 3 Standard Deviations), the device will again reduce the time between tests. On this occasion the next stimulus presentation will occur within the next 2 to 4 minutes. In its current application in open cut mines, the device has determined that the operator is at risk of becoming sleepy . A warning signal is sent to the supervisor at this stage, however, this will be hidden during the trial. This level of warning is referred to as an FC 3 (Fatigue Code 3).

3.1.2.4 Extremely slow responses

Extremely slow responses (more than 3 Standard Deviations or outside of 3 seconds) to stimuli presentations will cause the device to emit a warning buzzer sound in the vehicle cabin. This is not designed to increase alertness levels but to advise that the operator has responded extremely slow or missed the stimulus altogether. It is at this stage that the operator should no longer drive the vehicle without first having a rest/nap/sleep. Drivers within the research study were advised that they should utilise this warning sign and consider taking a rest or nap. Although this may reduce the amount of data collected within the trial, it will increase the safety of the drivers. This level of warning is referred to as an FC 4 (Fatigue Code 4) and in a mining environment, should be viewed as a high potential incident.

3.1.2.5 Faster responses

There are likely to be occasions whereby the reactions to the stimulus presentations were slow for reasons other than fatigue. For example, an operator may have been focussing all of their attention on something within their visual field, or may have been turning the steering wheel to move the truck around a tight corner. In this case, the next stimulus presentation will be sooner than 7 to 10 minutes apart dependent on the reaction time. If the operator then responds

quicker, the stimulus presentations will slowly move back out to the normal 7 to 10 minutes apart. Therefore, the quicker operators react to the stimulus presentations, the fewer tests will have to be conducted on that shift.

3.1.2.6 Safety

Operator safety has been given highest priority within all parameters of the investigation. The Project Leader has given priority to safety in every step of the project. The device is non-invasive and neither distracts nor causes high mental workload for the operators. This was supported by feedback from operators at safety toolbox meetings held on site.

3.1.2.7 Touch key

At the front of the reaction box is a receptacle for the 'touch keys' that is used to identify the operator using the FMD. The use of this facility is explained in the next section (Logging onto the device).

3.1.2.8 Logging onto the device

Each operator that uses the FMD will be issued with their own personal 'touch key'. Each time the operator uses a vehicle fitted with the FMD, they must touch their key onto the receptacle on the front of the reaction box. When they do this, it emits a beep indicating that they have logged on. It also identifies the operator and enables the system to use their personal reaction time data. When they have finished operating the vehicle, they log off by touching the key onto the receptacle again. When logging off, the device emits three short pip sounds to indicate the testing has finished.

If the operator forgets to log off at the end of operating the vehicle, one of two things will happen. If the next operator is part of the trial and he/she touches their key onto the receptacle, the device will automatically switch to their data. Nothing more will need to be done. If the truck is turned off, the operator will automatically be logged off.

3.1.3 Procedure

3.1.1 Baseline testing

Baseline data was collected for each individual who operated the test trucks throughout the trial. It was measured at the start of shifts when the operators were expected to be freshest. During the baseline testing, the device only recorded the reaction time information and tests were only performed every 7 to 10 minutes apart.

3.1.2 Real-Time testing

The FMD automatically switched to real-time testing after 20 baseline measures had been recorded. At this stage, all testing was conducted at the full potential of the device. In other words, slow reactions to stimuli presentations reduced the time between tests.

3.1.3 Sleep and Work Logs

A diary was developed for each driver within the trial to self-report on their total work and driving, rest and sleep times. Drivers were encouraged to self-report the data in an accurate

manner so that the outcomes of the trials would identify performance decrements that may be due to poor sleep hygiene rather than circadian influences alone.

3.1.4 Schedule of Work

The site utilised for testing was the Carosue Gold Mine near Kalgoorlie in Western Australia. It is owned by Sons of Gwalia and is operated by MacMahons. The current hours of operation are day shift from 0600 hrs to 1800 hrs and night shift from 1800 hrs to 0600 hrs. Each shift is of 12 hours duration. The roster is 14 consecutive night shifts followed by a day off, then 13 consecutive day shifts. In total, operators will work for 27, 12-hour shifts over a 28-day period. Operators were assessed for at least two consecutive rosters of work, taking around 10 weeks to obtain the data. In acknowledgment of the in-kind support offered by the mine, the organisation was offered solutions to any issues highlighted in the analyses of the data collected. Considerable time has already been spent on how this will be dealt with and is the basic reason for delay to the project.

3.2 Alcohol Comparison Methodology

An alcohol comparison was utilised to enhance the face validity of the data produced while testing drivers during day and night driving operations. Similar to the Williamson et al. (2000c) study, an alcohol performance comparison was conducted at the Murdoch University Driving Simulator by installing the FMD on the simulator.

3.2.1 Subjects

Fourteen subjects were recruited from contacts established through Murdoch University and ARRB Transport Research Ltd. Ages ranged from 19 years old to 52 years old. One subject dropped out of the trial after the first alcohol session. Occupations ranged from clerical duties, students, truck driver, chef, masseur, engineer and policeman.

Subjects had to meet the following stringent criteria.

1. They were not taking prescription or social drugs at the time of testing;
2. They had never suffered head trauma;
3. They had never presented with a psychological or psychiatric illness;
4. They were not undergoing medical treatment for anything at the time of testing;
5. They regularly drank at least five standard drinks per week;
6. They had no known medical conditions at all (eg. high blood pressure, diabetes, heart problems, etc), that may place them at any risk if they undertook the study, and
7. They have never presented, or suffered from an alcohol dependency.

These conditions seriously reduced applicants chances of taking part in the trial.

3.2.2 Apparatus

A STISIM driving simulator, comprising a half of a small Ford motor vehicle placed in front of a screen that had a scenic image projected onto it. The image had a refresh rate of every two seconds. The scene was a wide country road through slightly undulating hills. The drive was designed to last approximately 20 minutes. The system was controlled by a central PC that recorded vehicle movements made by the driver, such as headway speed and lane position. The

driving simulator was utilised as a primary task and an ARRB FMD was used as a secondary task, thus, the driving performance data was used only to ensure that the FMD tasks did not reduce the capabilities of the driving task.

A Lion's Alcolmeter was utilised to record blood alcohol content during the testing. The device was calibrated at the WA Police Service 'Breath Analysis Section' on 6 January 2003, using an Alcotest AR200C equilibrator Serial Number 96001 using a certified 0.100% ethyl alcohol solution heated to $34^{\circ}\text{C} \pm 0.1^{\circ}\text{C}$. The instrument was calibrated to indicate a result of 0.100 grams of alcohol in 100 millilitres of blood ± 0.005 grams of alcohol in 100 millilitres of blood. A copy of the calibration report is provided in Appendix 2.

3.2.3 Procedure

Subjects drove in the simulator for a two-hour period between 1600 hrs and 2000 hrs. In this time they collected baseline performance data whilst remaining totally alcohol-free. Each subject would then drive for two further two-hour sessions whilst becoming intoxicated. A counterbalanced design was utilised and subjects were tested between 2000 hrs and 2200 hrs, and 2200 hrs and 0000 hrs on a night a week apart. This was to compare whether or not the time of night had any influence on the intoxication performance. It was hypothesised that a fatigue-effect might be seen between the two alcohol sessions.

Within each of the alcohol sessions, subjects would drink vodka and orange/passionfruit carbonated soft drink. The aim was to get each subject intoxicated to approximately 0.05% BAC within the two hours of testing. Nearly all tests were performed on an ascending BAC. Subjects were progressively tested on a Lion's Alcolmeter and records of blood alcohol content (BAC) were made with time of night. This was to later correspond to performance through the sessions.

Subjects were driven home on all occasions after the alcohol sessions and were advised to not drive the following morning depending on the level of BAC reached during the testing.

4 RESULTS

4.1 Nightshifts in Succession

A total of 24 operators commenced the research at the minesite, with a few dropping out along the way. In total, approximately 3,500 hours of real-time performance data was collected for the study. Where operators only participated for a few hours, their data was eliminated. Some data was also eliminated where an operator forgot to log-off at the end of his/her shift and the device tested an operator outside of the study. The remaining 3,225 hours of data was utilised for analyses. There was 1,723 hours of data taken from nightshifts and 1,501 hours taken from dayshifts. The data presented within the results pertains mainly to the nightshift operation as it is likely that chronic fatigue and a short changeover period between working at night to working at daytime has affected the results of the daytime data. A sample of daytime data will be shown where appropriate.

Thirteen operators returned their Fatigue Risk Questionnaires and only one operator returned his sleep diary. The sleep diary component was therefore eliminated from further investigation. Of those who returned their Fatigue Risk Questionnaires, seven (>50%) were obese as indicated by a body mass index over 30. Further, two had serious sleep disorders and two had minor disorders such as snoring.

There are two basic questions that require answering within this study:

1. What is the most important contributor to acute fatigue in open cut mining? Is it length of shift (eg. 8 hours Vs 12 hours) or is it time of day (eg. circadian effects)?

2. What is the limit of successive day or night shifts before chronic fatigue affects operator performance in open cut mines?

4.1.1 Length of Shift Versus Circadian Influence

To answer the first question, only the data from the first nightshift will be used. This is to avoid any possibility of operators commencing the second nightshift with cumulative fatigue, either from the work operation itself or the lack of quality sleep during the first daytime sleep session.

If the length of shift (eg. 8 Vs 12 hours) has an effect on operator fatigue, one would expect that performance would deteriorate in a somewhat linear pattern throughout the course of the nightshift (especially after 8 hours of work). In this case, performance would be expected to be worse in the 12th hour of work than the 11th, which would be worse than the 10th, and so on.

If circadian effects were a stronger predictor of performance, then a performance decrement should be seen between the hours of midnight and 0600 hrs. This would reflect data from sleep studies and some fatigue-crash studies. Figure 2 plots the performance data collected by the time of night to show how performance is affected over time. It has a 'z-score' line reflecting a circadian influence on performance. It is taken from Mabbott and Newman (2000), whereby the authors have weighted hours of work to reflect the circadian influence on crashes. Put simply, if the performance data follows the z-score, it would indicate that the circadian influence is present.

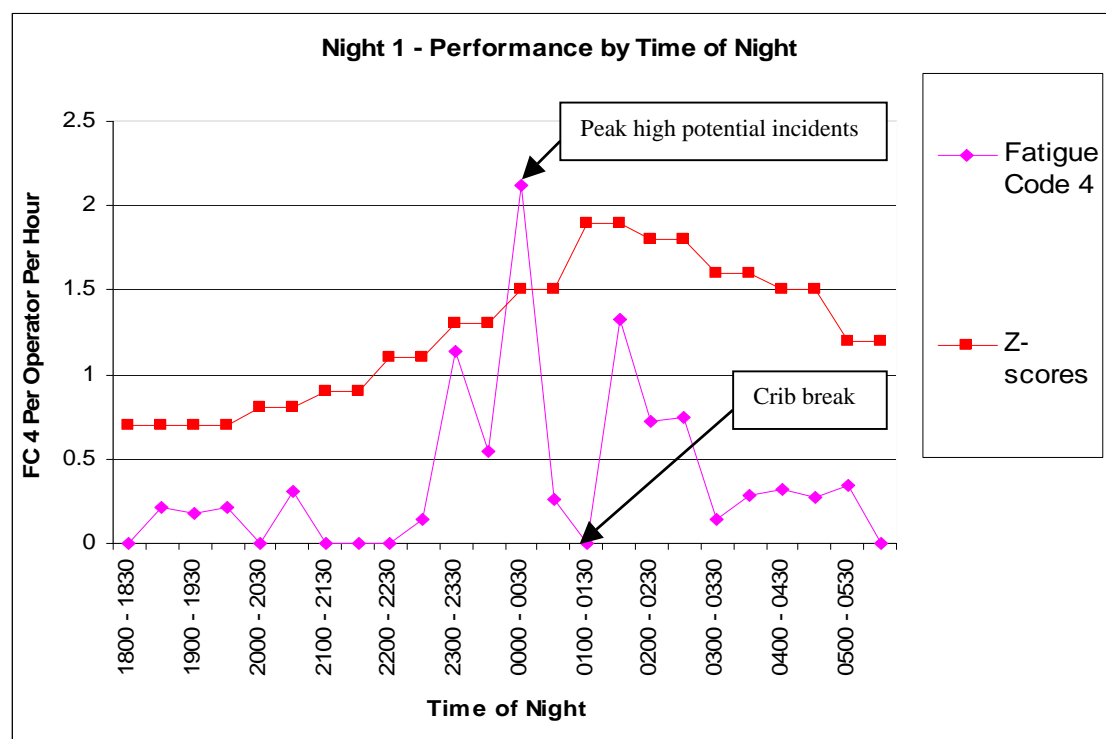


Figure 2: Nightshift one performance data by time of night.

Fatigue code 4's (FC 4's) have been used to demonstrate the most severe performance decrements throughout the night. This is where operators either did not respond to the stimulus presentation within four seconds, or they responded more than three standard deviations slower than their mean reaction time. Translated to safety terms, this would indicate a high potential incident for each of the FC 4's shown, as operators are responding dangerously slow. The scale on the left indicates the average of all operators per hour over the time of night. For example, at around 0030 hrs, there were just over two fatigue code 4's per operator per hour. If all eight

trucks were operational at the time, this would equate to 16 high potential incidents over the hour on average. The effect of a crib break is seen between 0045 hrs and 0130 hrs, however, the effect is short-lived and performance decrements reach their second peak through the night at around 0145 hrs.

It is clear from the performance data illustrated in Figure 2, that performance decrements peak approximately midway through the night and again shortly after the main crib break. This does not in any way support the argument that 12 hours of operation is more tiring than eight hour of work (on the first nightshift). In fact, the worst of the performance data is over by 0330 hrs (9.5 hours of operation). There is a circadian influence present, as shown by the FC 4's following the z-score trend. Although it is not a perfect fit, it illustrates that performance is highly affected by the circadian influence.

4.1.2 Successive Nightshift Operations

What is the limit of successive day or night shifts before chronic fatigue affects operator performance in open cut mines? To answer this second question, data was obtained and analysed for the successive nightshifts from night one through to night 14. Similar to the first question, there are likely to be different influences on operator performance. The most presumptuous of these differences would be the circadian influence and number of nights worked in a row. Figures 3 through 15 illustrate the successive nightshifts worked from night two through to night 14. At this point, the operators get a 24-hour break before commencing dayshift operations.

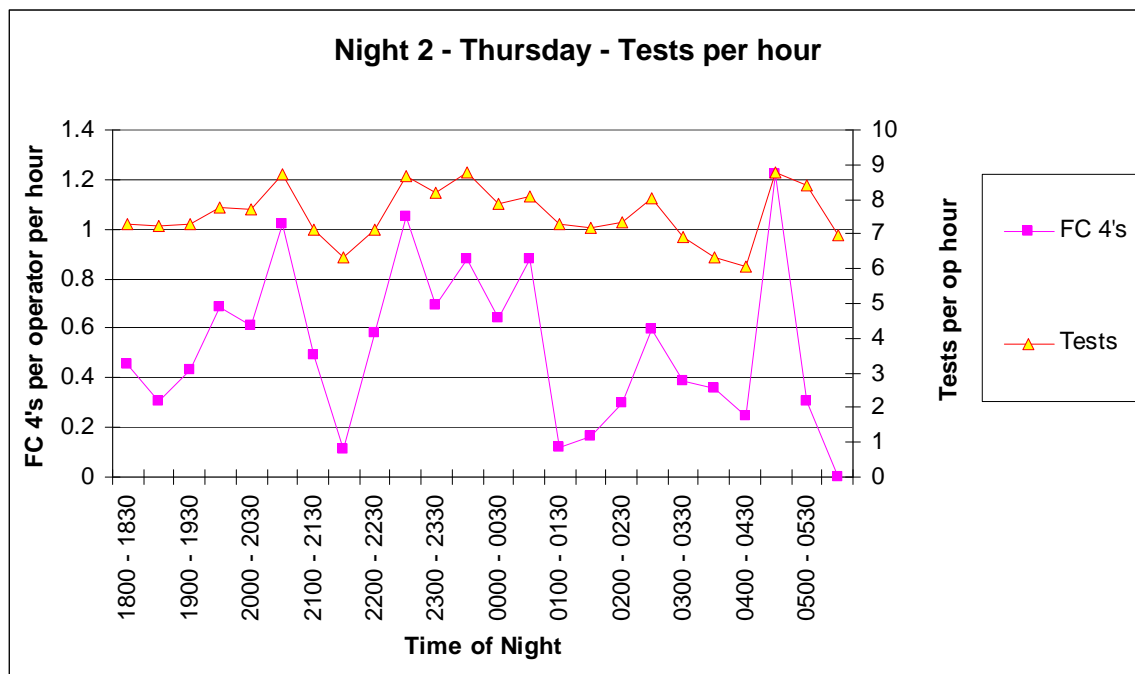


Figure 3: Nightshift two performance data by time of night.

In this and subsequent Figures (3 to 15) fatigue code 4's are shown, along with tests per operator per hour. Tests per operator per hour are shown to reflect the number of stimulus tests presented to operators. As drivers are tested more often when they react slowly, the tests per hour offers a general level of tiredness as opposed to the more severe FC 4's. Once again, FC 4's are scaled on the left of the graph and tests per hour are scaled on the right.

Note a completely different pattern of performance decrement as opposed to the first nightshift performance data. Instead of showing a bimodal peak as in Figure 2, there appears to be a

consistent few hours from 2045 hrs to 0045 hrs whereby operators show performance decrements. This appears to dissipate somewhat after the crib break and reaches a peak around 0445 hrs. This follows neither a circadian pattern nor a length of task pattern.

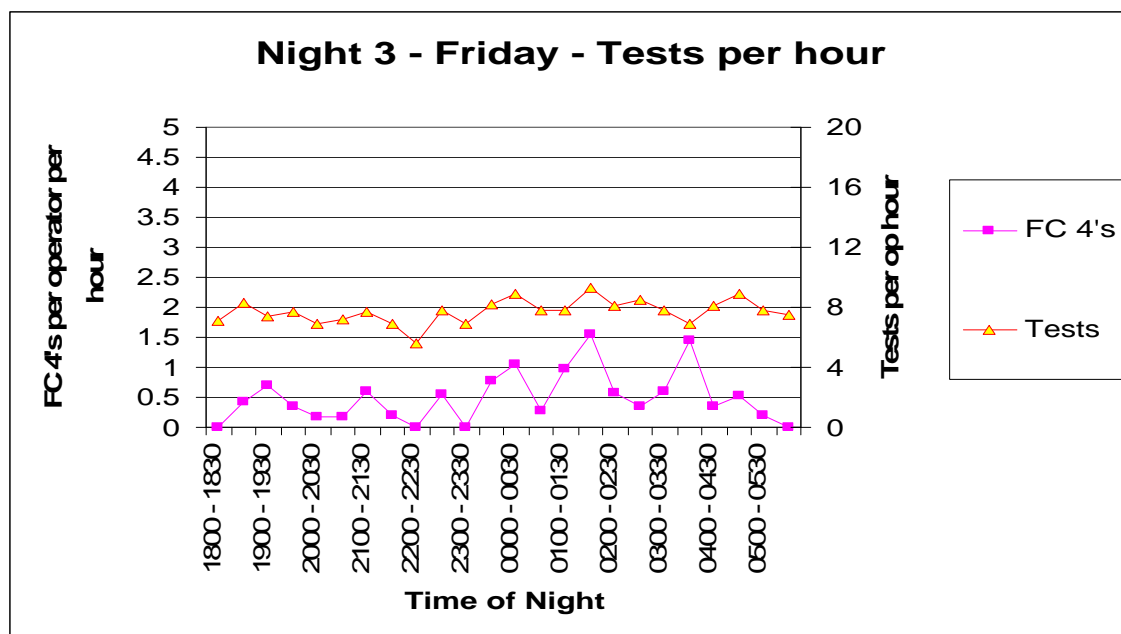


Figure 4: Night three performance data by time of night.

Figure 4 shows that night 3 is almost the opposite of night 2, in that most of the performance decrements appear in the latter half of the night. There is a bimodal peak of FC 4's, at 0145 hrs and 0345 hrs. This trend follows a circadian influence.

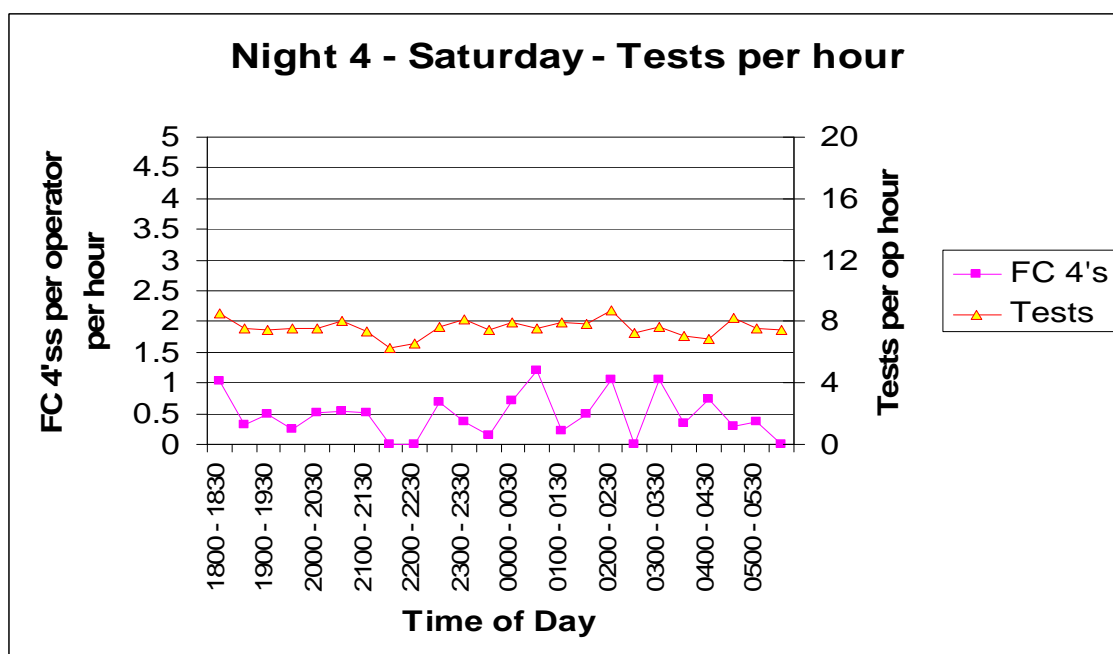


Figure 5: Night four performance data by time of night.

Night four appears to be very similar to night three with most performance decrements following a circadian trend in the second half of the shift.

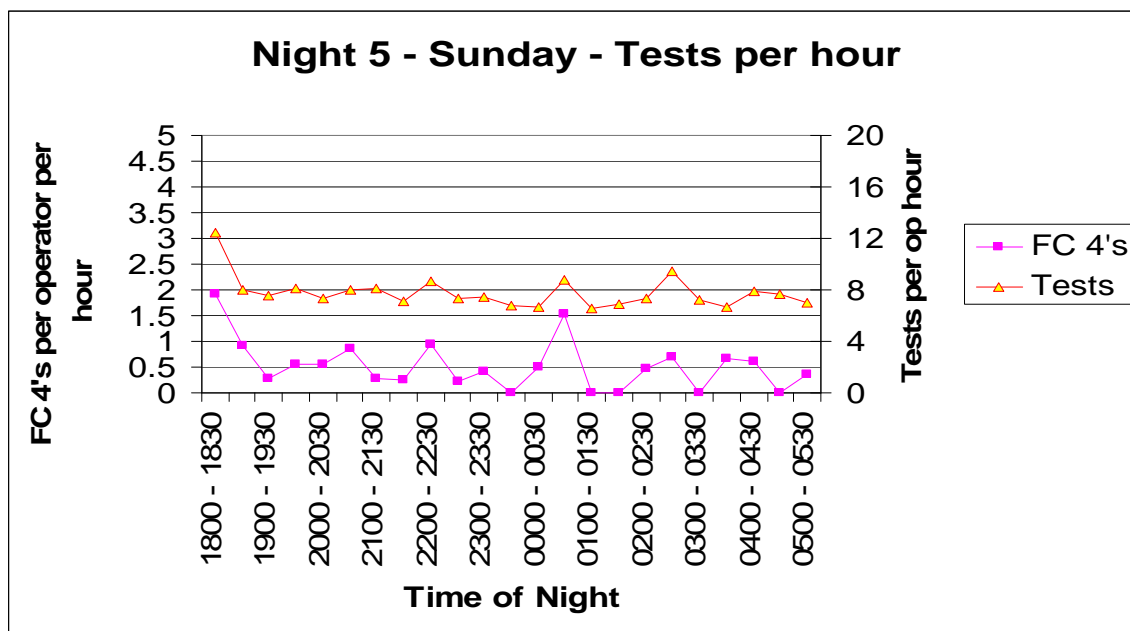


Figure 6: Night five performance data by time of night.

Night five is a more constant night regarding performance. It does not follow any trends regarding circadian influence or time on task. Interestingly, the first half of the night tends to be worse than the second half regarding operator performance.

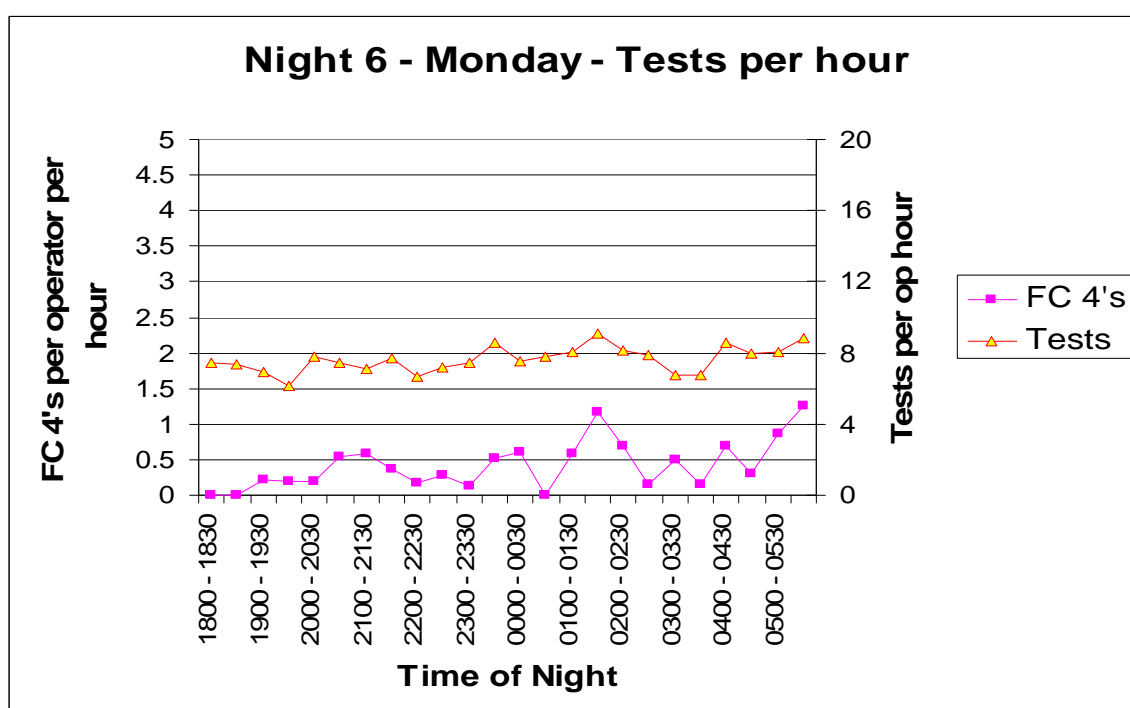


Figure 7: Night six performance data by time of night.

Night six is performed with few FC 3's and FC 4's until 0145 hrs and again near the end of the shift. This is one of the better performances over the successive nights thus far.

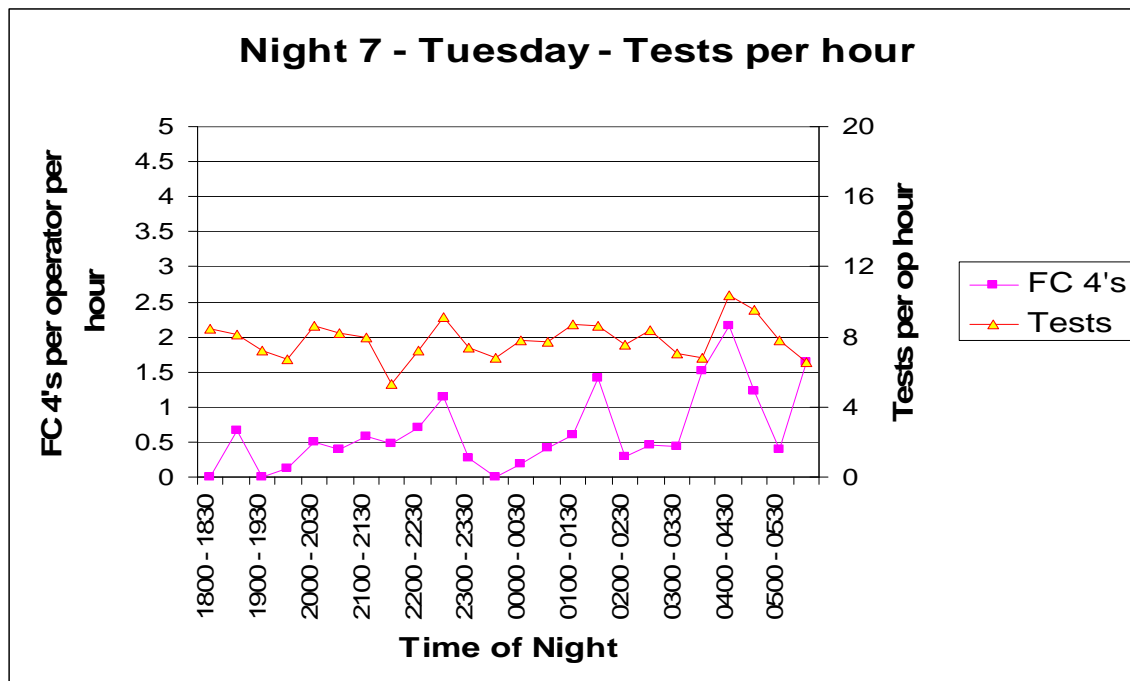


Figure 8: Night seven performance data by time of night.

There is a significant performance difference from the previous night (six) to the seventh. Performance decrements peak prior to midnight and a further two times between 0145 hrs and 0430 hrs. The major peak is toward the end of the shift indicating that the circadian influence on this particular night is second to a stronger influence that may be time on task related. Overall, this is the worst performance night of the first seven.

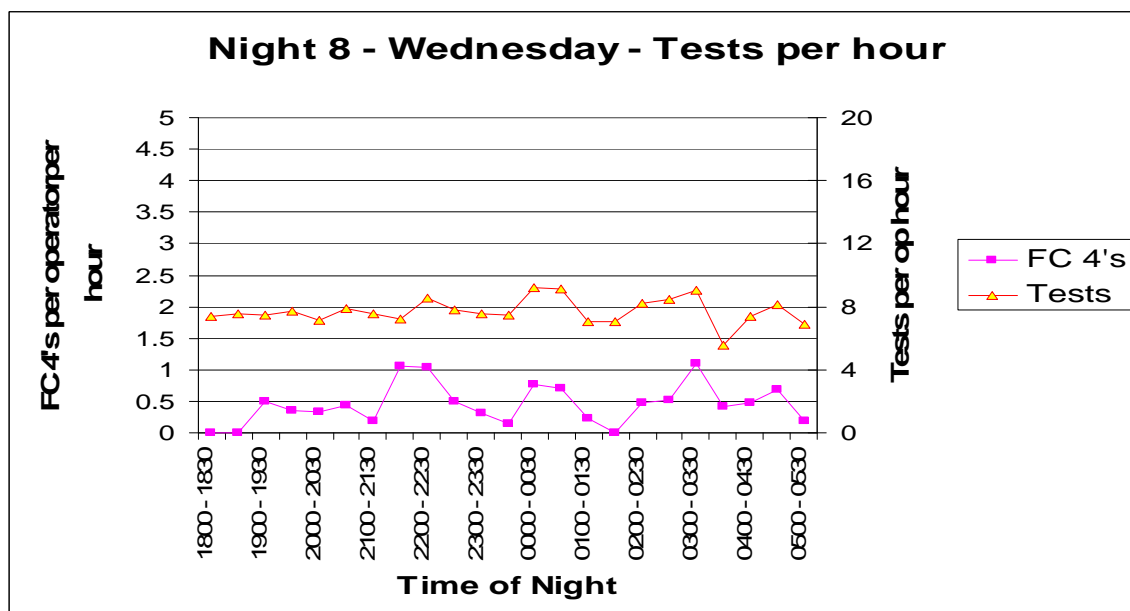


Figure 9: Night eight performance data by time of night.

Night eight is a better night performance-wise than night seven, with no peaks rising above 1 FC 4 per operator per hour. Although better than night seven, there are still circumstances where operators are exhibiting an average of one high potential incident per hour for much of the night. It is counterintuitive that performance would be better after one more night of work.

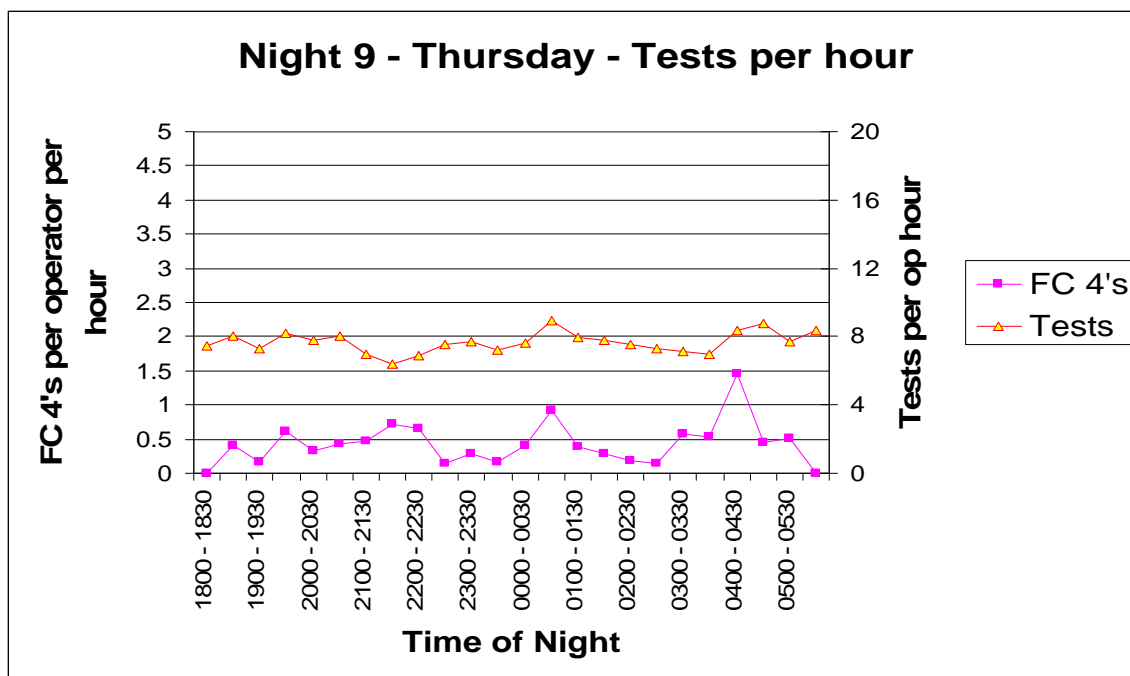


Figure 10: Night nine performance data by time of night.

Further improvement in performance is shown for night nine, whereby the peak in performance decrement is seen at 0430 hrs.

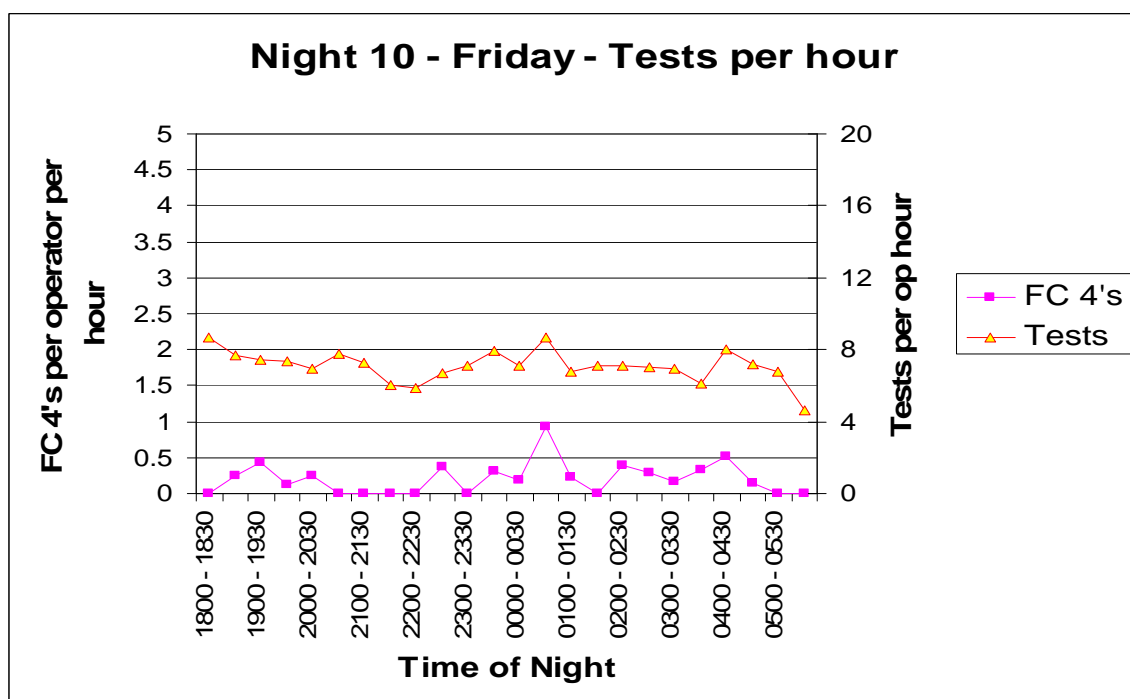


Figure 11: Night ten performance data by time of night.

Night ten shows the best performance data over the whole of the fourteen nights in succession. Note that only on one occasion do performance FC 4's reach one per operator per hour (0045 hrs). Otherwise, there are less than half an FC 4 per operator per hour for the remainder of the night. Intuitively, one would expect that the performance on night ten of successive 12-hour shifts would be significantly impaired compared to the earlier shifts.

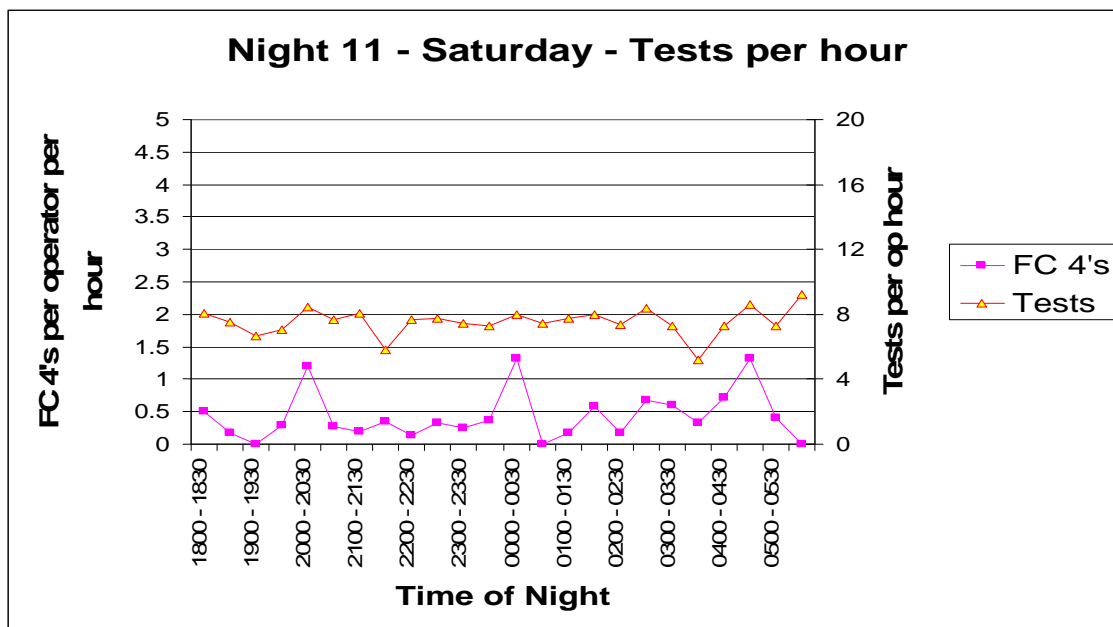


Figure 12: Night eleven performance data by time of night.

At night eleven, performance begins to decline again, with peaks above one FC 4 per operator per hour at 2000 – 2030 hrs, 0000 – 0030 hrs and 0445 hrs. However, such performance is still better than performance during many of the earlier sessions.

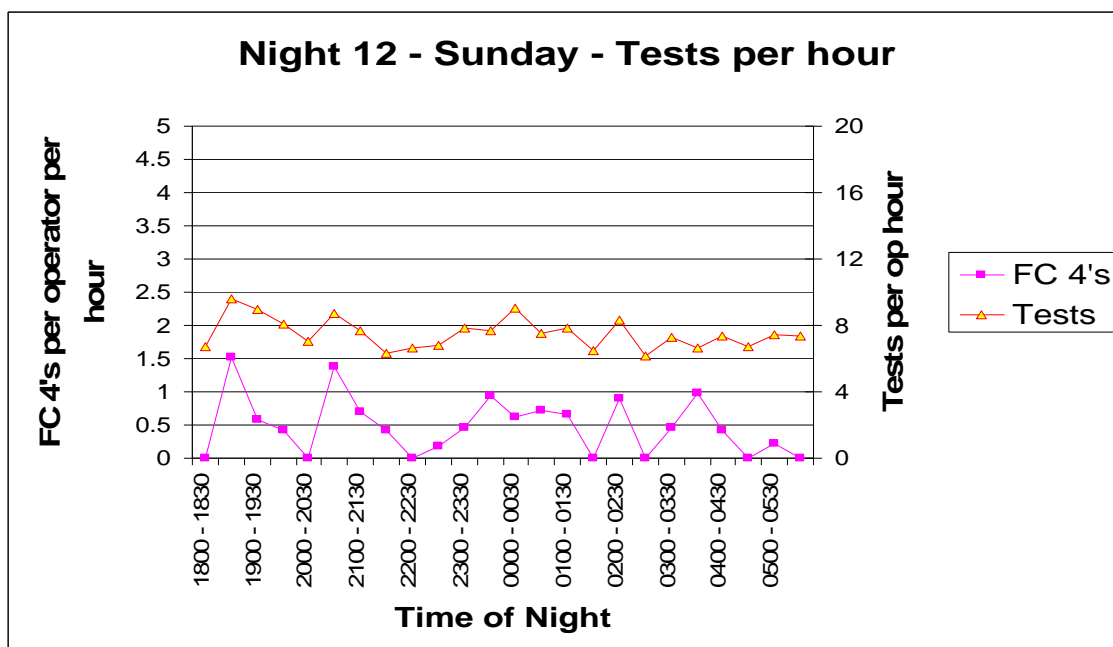


Figure 13: Night twelve performance data by time of night.

Night twelve shows a return to performance as seen early in the sessions. Although neither a circadian nor time on task influence is demonstrated, there appears to be a constant fatigue issue through most of the night. Similar to the first Sunday night, there appears to be performance issues early in the night.

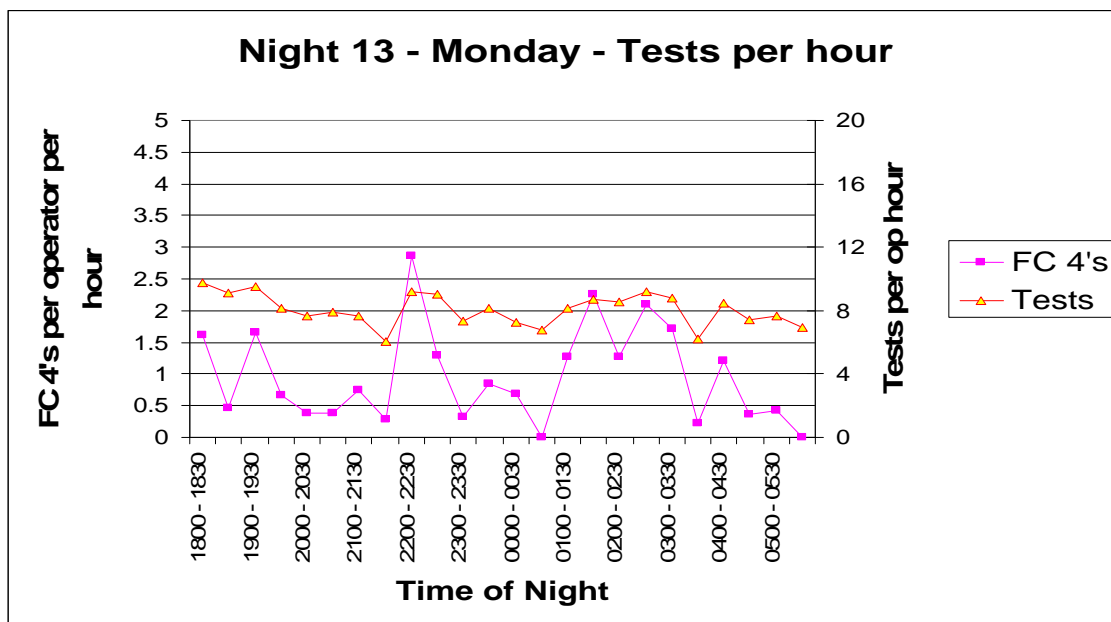


Figure 14: Night thirteen performance data by time of night.

Night thirteen shows the worse performance data of all sessions. It has the highest peak of performance decrements, indicating that if all trucks were running at 2200 hrs, there would be approximately 24 high-potential incidents (3 per operator per hour x 8 trucks). A further disturbing peak occurs from 0145 hrs and runs till approximately 0330 hrs. It is surprising that many fatigue events are not being recorded on night 13 of operator's shifts.

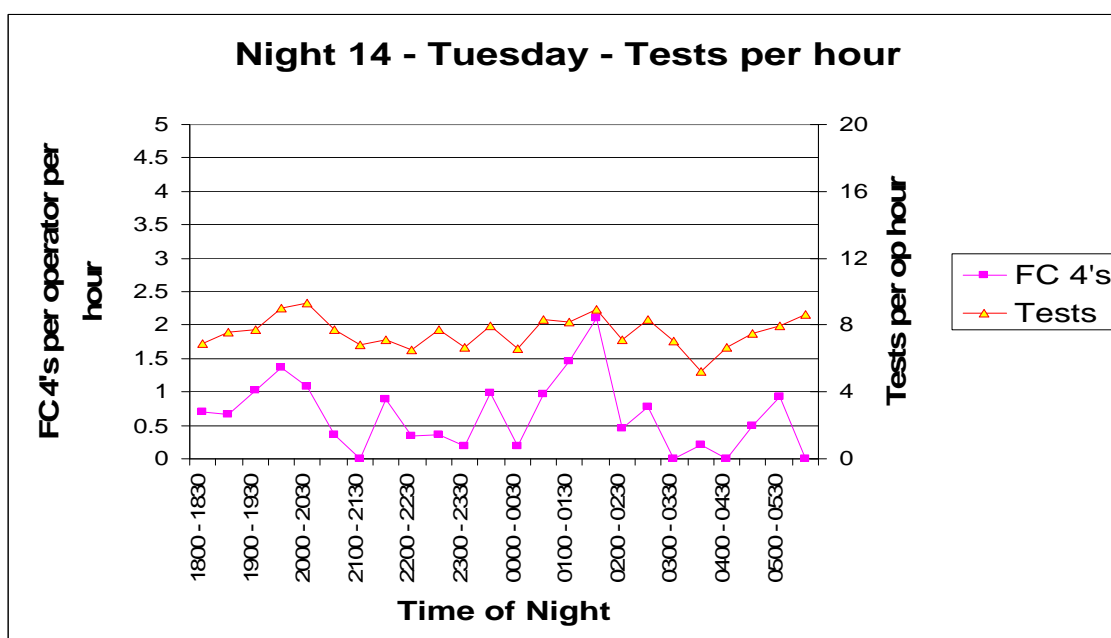


Figure 15: Night fourteen performance data by time of night.

Following what can only be described as a very dangerous thirteenth night, night fourteen finishes off the nightshift roster with another dangerous performance. In this case there is a dangerous peak at 1945 hrs, at a time where previous research has shown that people have some trouble attempting to get to sleep even after a night of sleep deprivation (Lavie, 1985). Lavie argued that there is a 'forbidden zone' for sleep centred around 2000 hrs to 2200 hrs, approximately an hour or two prior to the subject's normal sleep onset time. This occurred in Lavie's research even after a night of sleep deprivation. This may suggest that subjects within this study are beyond the influence of the equivalent of one night's sleep deprivation. However, it must be noted that this study is measuring reaction performance and not sleep per se. Similar early fatigue occurrences (eg, 2000 hrs – 2200 hrs) were also shown on nights 2, 5, 8 11, 12 and 13. Two of these nights (5 & 12) were Sunday nights and operators mentioned they may have been tired due to not getting enough daytime sleep as football and rugby was on television when they should have been sleeping.

Two information sessions with operators were conducted on site to discuss the findings. Importantly, operators stated that the data appeared to support how they felt whilst operating the haul trucks throughout the 14 nightshifts. This gave the FMD excellent face validity as the operators 'believed' what they saw. They also commented on some of the anomalies, such as the Sunday night performance.

4.1.3 Finding the Limit of Successive Nightshifts

Figure 16 below sets out the full 14 nightshifts and displays the average number of FC 4's per operator per hour, which indicate the high potential incidents occurring at the trial site. It is easy to determine that nights 13 and 14 are potentially dangerous with over one high potential incident per operator per hour for night 13 and 0.7 high potential incidents per operator per hour on night 14. One might argue that if these two nights were removed, the pattern of reduced performance may transfer to nights 11 and 12. When discussed with operators, they mentioned that they tended to relax more and not fight tiredness so much as they knew they were close to the end of the night work.

What then becomes of nights 2 and 7 as they are both worse nights for performance than any of the others within the first 12 nights? It is this type of anomaly that suggests that to simply put limits on nightshifts in succession, may not go far to eliminating the risk of fatigue and reduced operator performance. In fact a misconception may be that fatigue will not be present in a roster where only a few nights in a row are conducted. The objective performance data collected within this study proves beyond any reasonable doubt that operators may get dangerously tired within the first two nights.

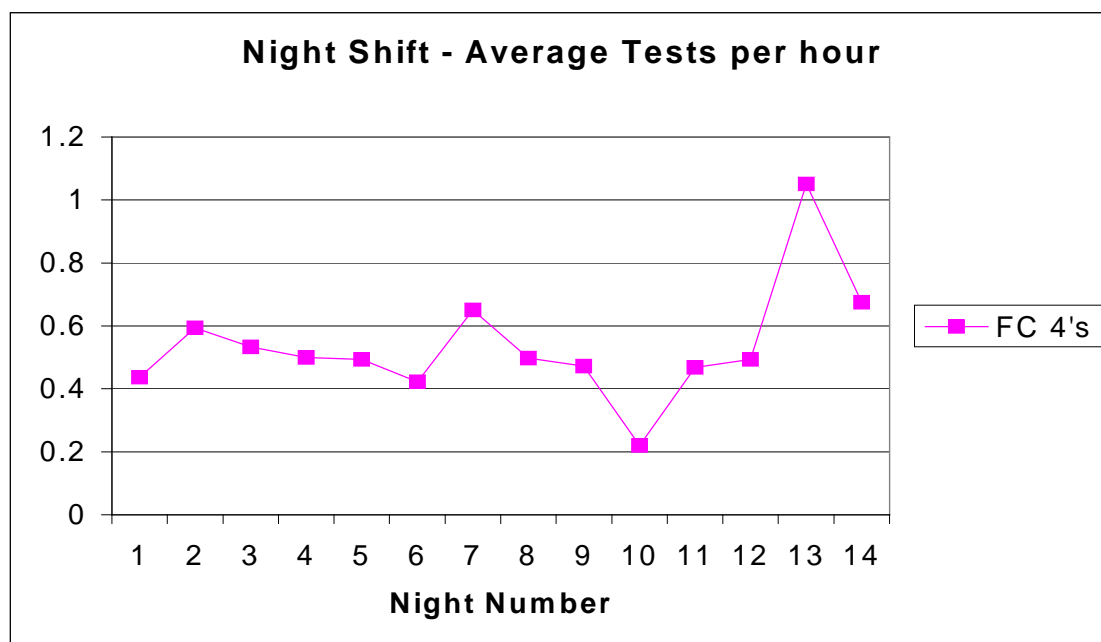


Figure 16: Average FC 4 performance per operator per hour over entire fourteen nights of operation.

4.1.4 Circadian Factors

It is interesting to note that operators within this study have performed poorly at times when circadian influences are expected to create a drive for sleep and also at times when humans are said to have a 'forbidden zone' for sleep even after sleep deprivation. This again suggests that it is unwise to presuppose that humans will get tired only in accordance with popular beliefs (even if well supported in research).

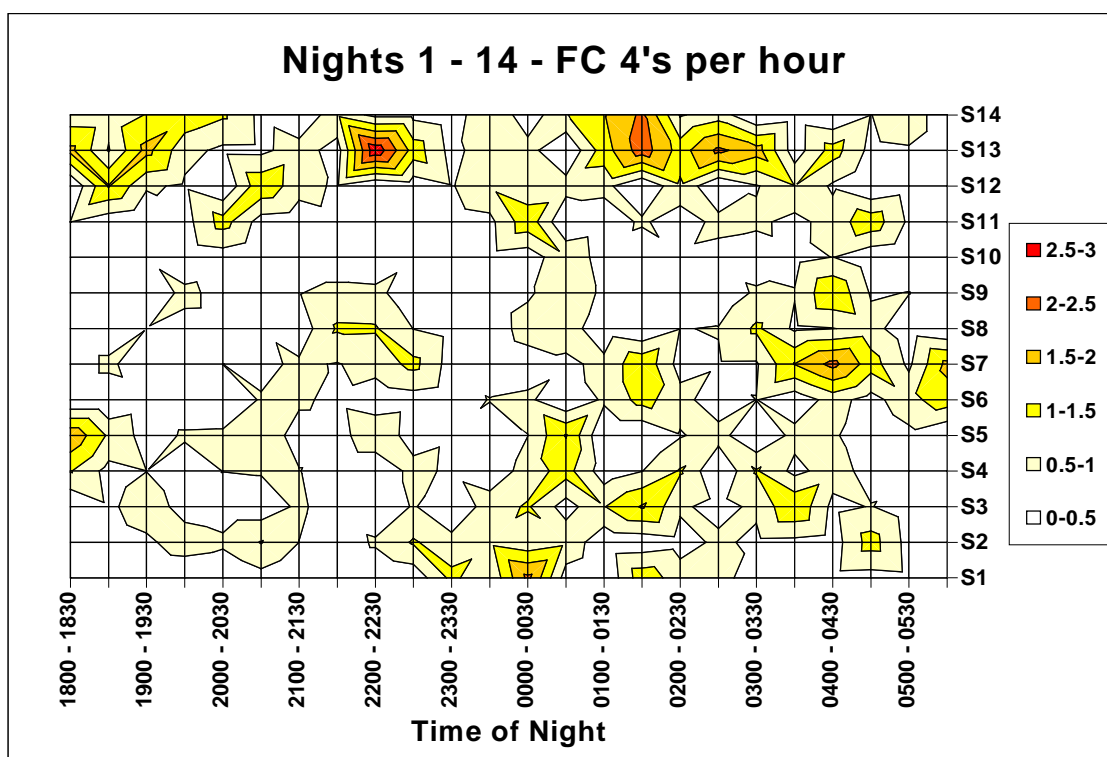


Figure 17: FC 4's plotted by time of day. Darker patches represent high potential for fatigue incidents.

Figure 17 clearly illustrates that a circadian influence is present. The graph shows FC 4's per operator per hour for each of the night sessions (S1 – S14). The peak period for FC 4 responses is between midnight and 0500 hrs. However, it is also clear that operators are getting tired before midnight on many occasions. From this graph it is suggested that circadian factors have a stronger influence on fatigue than do nights in succession, with the exception that nights 13 and 14 are extremely poor throughout the whole shift.

4.1.5 Individual Variability

Hanowski *et al.* (2003), like others before them, have noted that a small percent of drivers contribute to a large percent of critical incidents. This being the case, the data was examined to determine what influence individual differences had on the critical incidents detected within this study. Figures 18 and 19 below show a sample of the individual variability within the sample of operators at the research site. The graphs show FC 4's averaged over the full 14 nightshifts for the operator by time of night. It can easily be demonstrated that there are significant differences between the two operators. Operator X, for example, averages around two FC 4's on any given hour of the night. Further, the operator has severe problems around 0145 hrs, when reaching an average of 6.5 FC 4's for the hour. Operator Y, has a much better performance with less decrements per hour (between 0.5 & 1 per hour), than operator X.

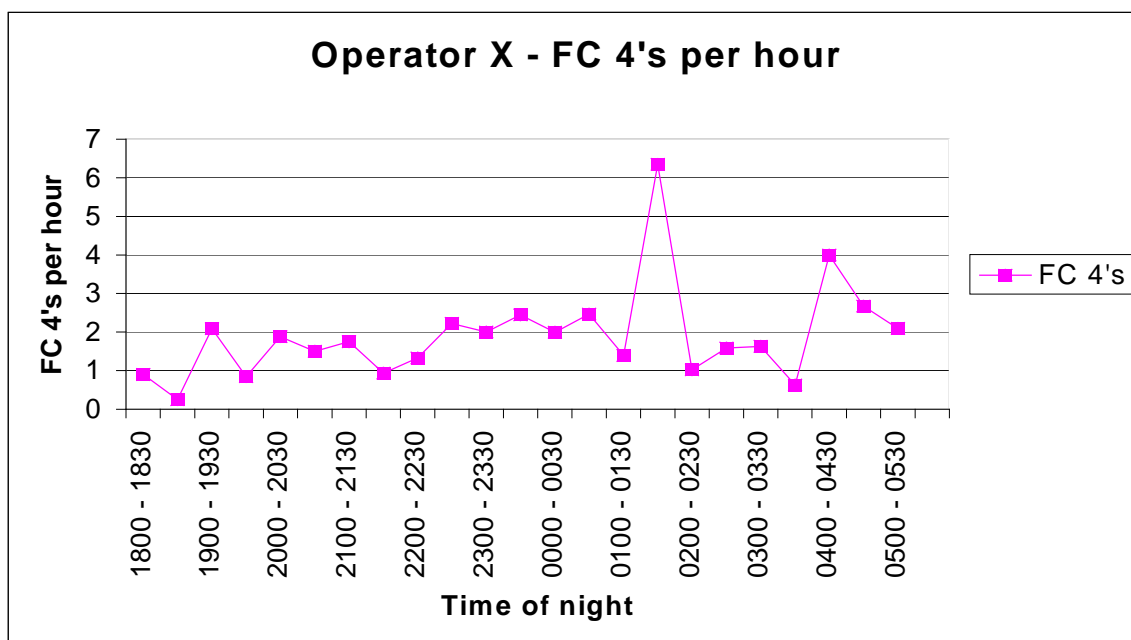


Figure 18: FC 4 average performance per hour over all nightshifts for operator X.

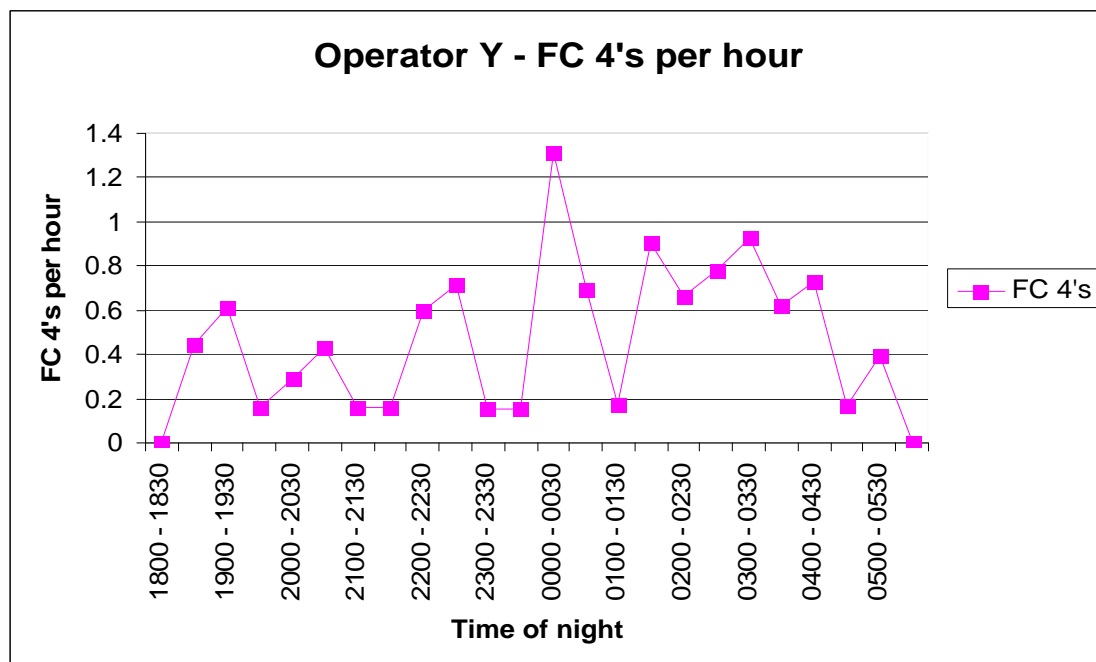


Figure 19: FC 4 average performance per hour over all nightshifts for operator Y.

A question not asked within this study is: 'Can you predict an operator's performance over successive nightshifts'? Referring back to the Hanowski study, whereby less than 25% of the drivers were responsible for more than 85% of critical incidents, it stands to reason that to have a form of performance prediction would be most useful. For example, if one could predict future performance of individuals, it would assist in fitting the person to the task or putting change management strategies in place. The data was analysed to determine what percent of operators contributed to the majority of high potential incidents as recognised by FC 4's. It is noted that 25% of the operators within this study contributed to 55% of the FC 4's and 50% of the operators contributed to 80% of the FC 4's. This allows us to determine where to focus attention to reduce the high number of FC 4 incidents.

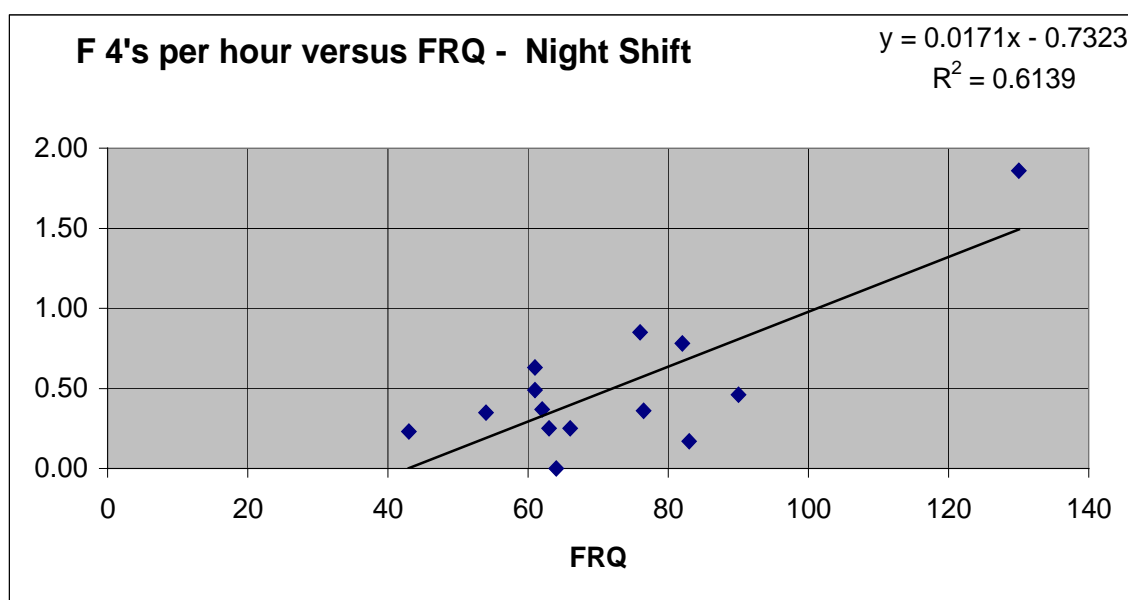


Figure 20: Correlation between scores on the Fatigue Risk Questionnaire and high averages of FC 4's.

The use of the Fatigue Risk Questionnaire (FRQ) scores serves as a tool for predicting to some extent, who are likely to be poor performers (or good performers). Figure 20 shows the significant positive correlation (r^2 (d.f.14) = 0.6139; $p < 0.05$) between high scores on the FRQ and high averages of FC 4's for operators. This allows identification of those who are contributing the worst performance so that changes can be made. The operators within the study have received recommendations that may assist them to perform better. Two have also been recommended to a general practitioner to follow up on possible sleep disorders.

4.1.6 Summary of Nightshifts in Succession

There are several very interesting and important findings within this study. First, the data collected showed that for a single night of driving haul trucks, there appears to be no affect on performance from the amount of time on task (for the 12 hours). It was clear that the circadian influence had a stronger affect than working more than eight hours.

The analyses undertaken to determine how many successive nightshift operations could be undertaken before becoming a safety issue, was considerably enlightening and somewhat counterintuitive. Common sense would suggest that as the number of successive nights increased, so would the number of high potential incidents. This was clearly not the case. Of the fourteen nights, nights thirteen, fourteen, seven and two respectively, were the worst.

The major finding within this study is the combined influence of circadian rhythms and individual variability. It is somewhat comforting to note that a certain level of prediction can help to assist in determining who might present as a safety issue.

4.1.7 Sample of Daytime Data

A sample of daytime data is provided to illustrate a few concerns with moving from nightshifts to dayshifts with only one day in between to make the adjustment.

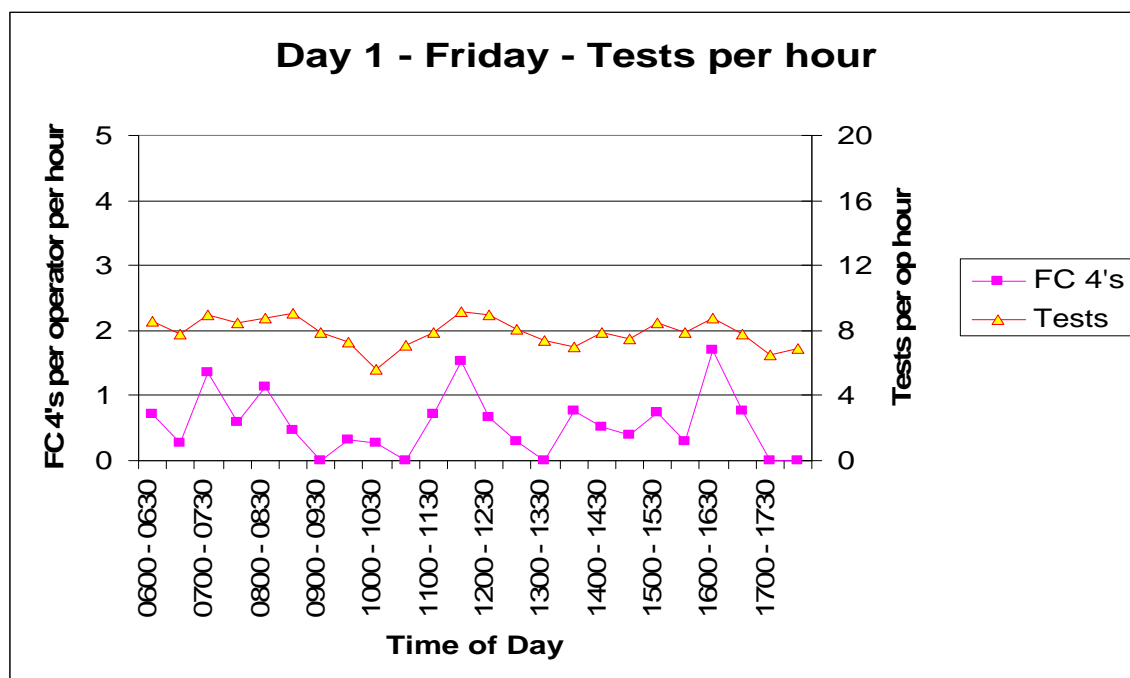


Figure 21: Day one performance data by time of day.

Figures 21 and 22 illustrate that the transition from nightshift operation to dayshift operation has been anything but successful. It is clear that high potential incidents are occurring within the

first few hours of the commencement of dayshift work. Further, the incidents continue through much of the day. Day two is similar and the performance decrements are again present through most of the shift.

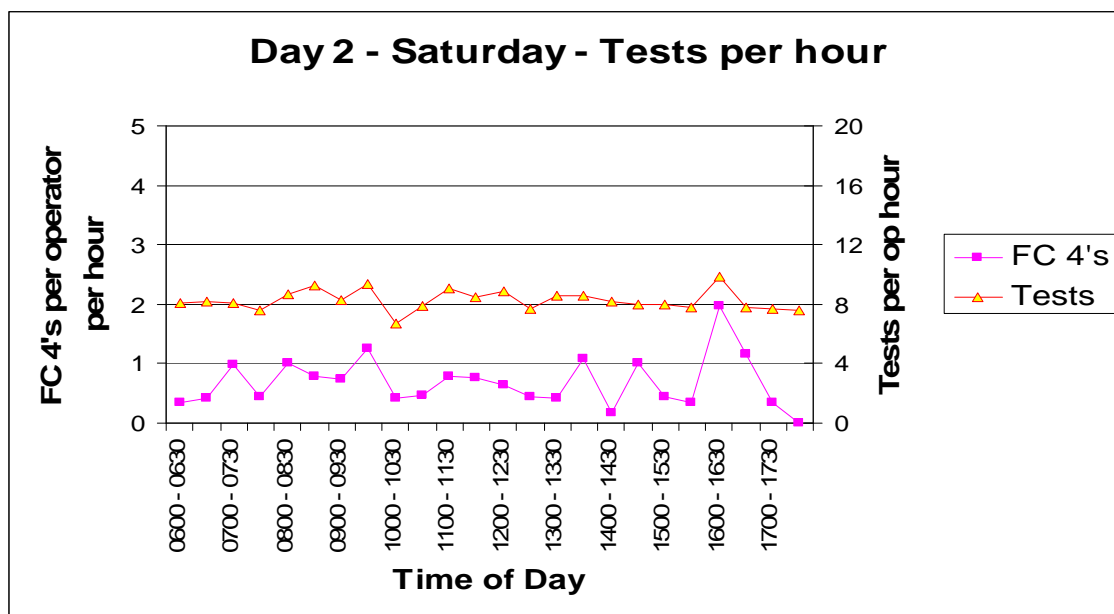


Figure 22: Day two performance data by time of day.

Further, similar to nightshift operations, some days (eg. day eight) are particularly worse than others, while the following ninth day is a much better day for performance. Day eight is shown below in Figure 23. This graph shows serious performance decrements throughout the day and in particular, the afternoon, where it peaks at 3.5 FC 4's per operator per hour.

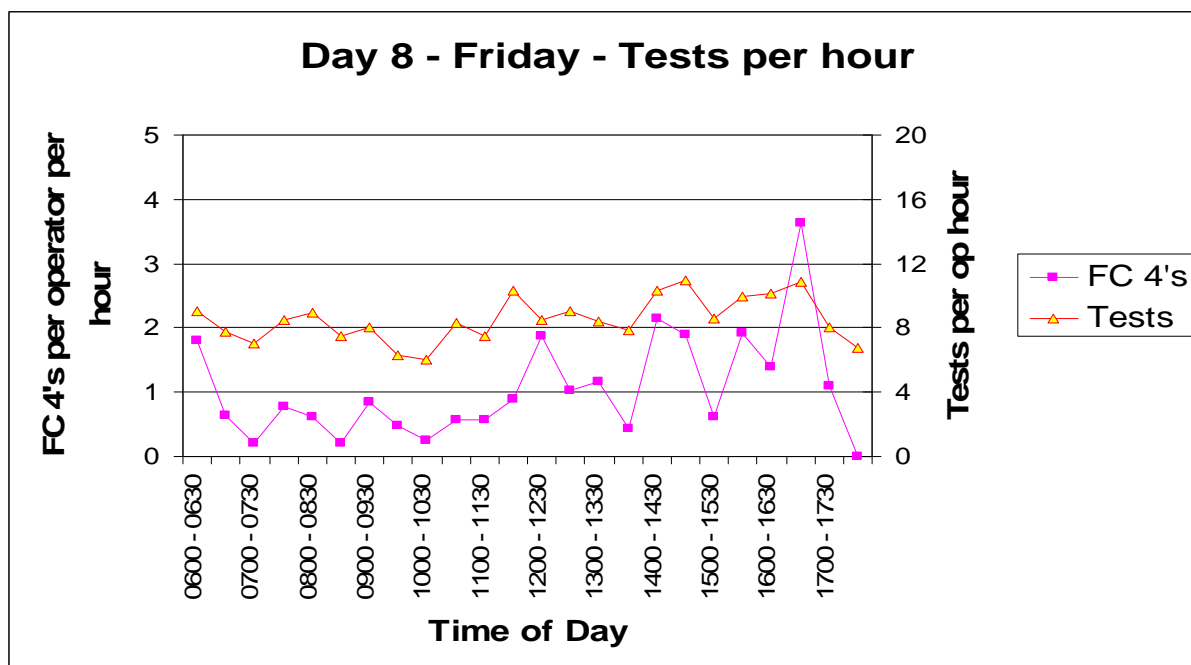


Figure 23: Day eight performance data by time of day.

Figure 24 below plots the FC 4 performance profile over the thirteen dayshift periods. Similar to Figure 17 for nightshifts, the plot allows performance to be shown through the time of day and for each of the 13 nights. There are clear circadian effects shown as the dark patches indicating that FC 4's are prominent in the afternoons between 1200 hrs and 1730 hrs. Also note the poor performance on day eight (S8).

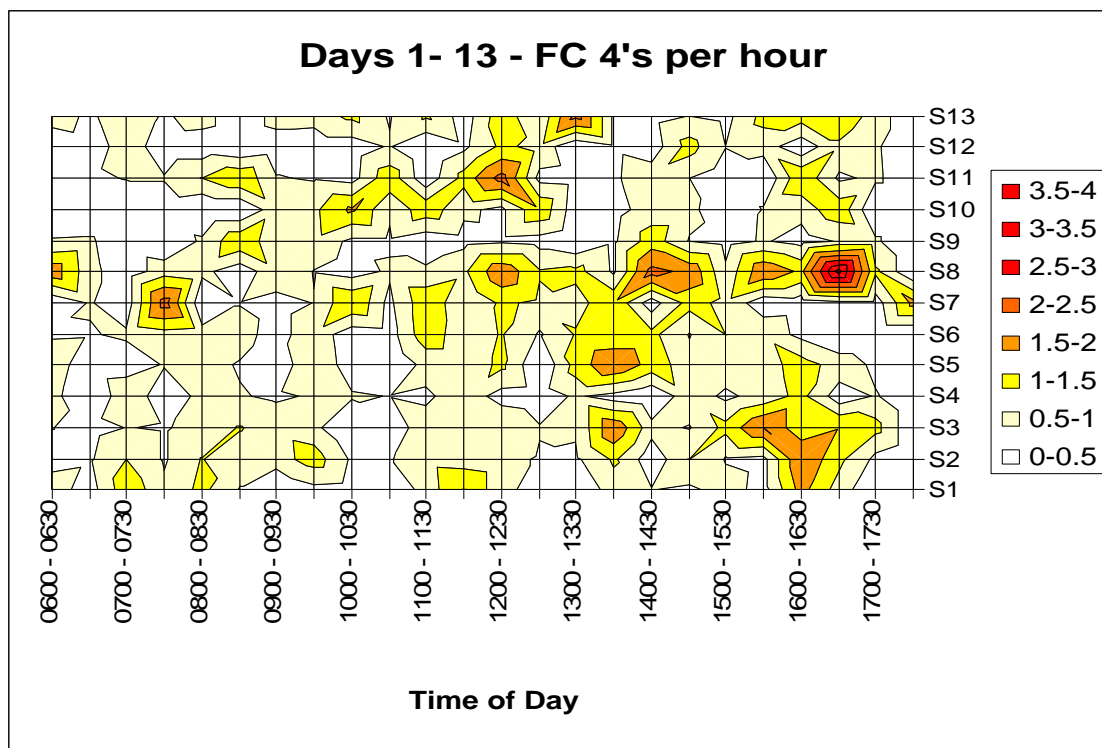


Figure 24: FC performance data for all 13 dayshifts.

It appears from the graphs of daytime data, that performance for any of the days of operation following the 14 nights, is very poor. It is clear that more time is required (post-nightshift) for operators to obtain rest and sleep before commencing a further 13 days of continuous operation.

4.2 Alcohol & Reaction Times

One male subject only tested once as he vomited after his first alcohol study session. One other female subject pulled out approximately half way through her second alcohol trial. Most subjects reached just under 0.05% BAC, with a few reaching higher BAC levels. One subject made 0.1% BAC.

Subjects were BAC tested approximately every fifteen minutes during the testing. At each test, they would be asked if they felt they should still drive. Out of 27 alcohol sessions, all but on one occasion, subjects said they would stop driving at 0.02%BAC. Most commented that they didn't feel they were performing too well and would not like to be driving on the road in the condition they were in.

In total, 28 hours of control data was collected and 54 hours of alcohol experimental data. There were 28 hours of data for between 2000 hrs and 2200 hrs, and 26 hours of data for between 2200 hrs and 0000 hrs.

Data were recorded for all responses to the performance tests. The output data would include responses for 'incorrect' (eg. left arrow and hit right button) and responses that were more than one, two or three standard deviations slower than the subject's mean response data. There appeared to be a few speed/error trade-offs, whereby subjects would attempt to respond quickly but in the attempt, hit the wrong response button. Figure 25 below shows the general results of all measures of incorrect or slow responses for all subjects over all alcohol testing periods. The results are shown as errors and slow responses per driver per hour.

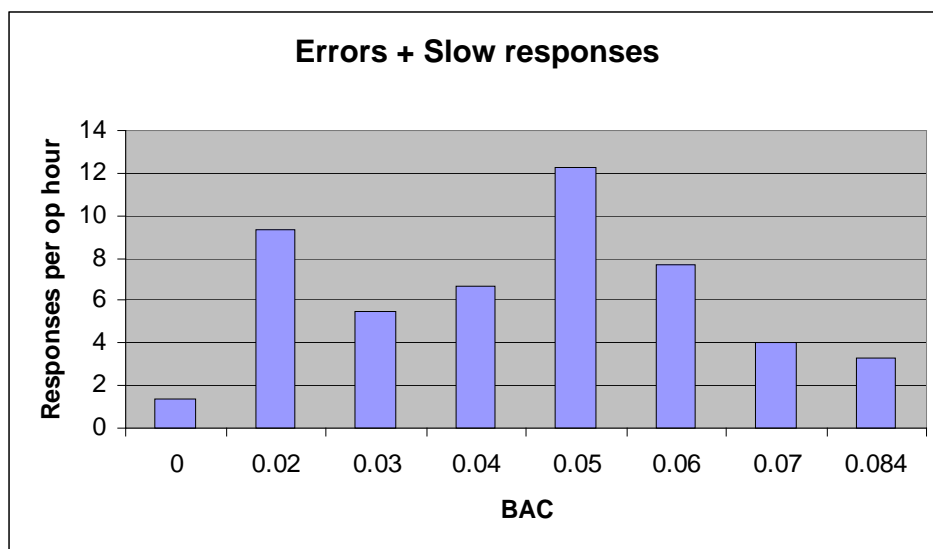


Figure 25: General errors and slow responses by BAC levels.

Note the rapid rise in slow and incorrect responses at BAC of 0.02%. It is interesting that after the sudden rise in errors and slow responses at 0.02% BAC, a better performance is shown up until 0.04% BAC. It again increases at 0.05% BAC. The initial return to better performance at 0.03% BAC indicates that the drivers may have realised they were not performing well at 0.02% BAC and adjusted their focus between primary and secondary tasks. If this is the case, they would have been focussing less on the driving task and more on responding correctly and quickly. This trade-off may not have been possible for subjects once they reached 0.05% BAC, as both their performance on the driving simulator was slightly reduced and their reaction performance was significantly reduced.

As there were only a few hours of data for subjects driving at 0.07% and 0.08% BAC, the data reflects a few individuals who were generally more experienced at drinking, thus, more experienced at managing the effects of the BAC. Therefore, all data corresponding to BAC over 0.06% should be considered as not representative of the whole group.

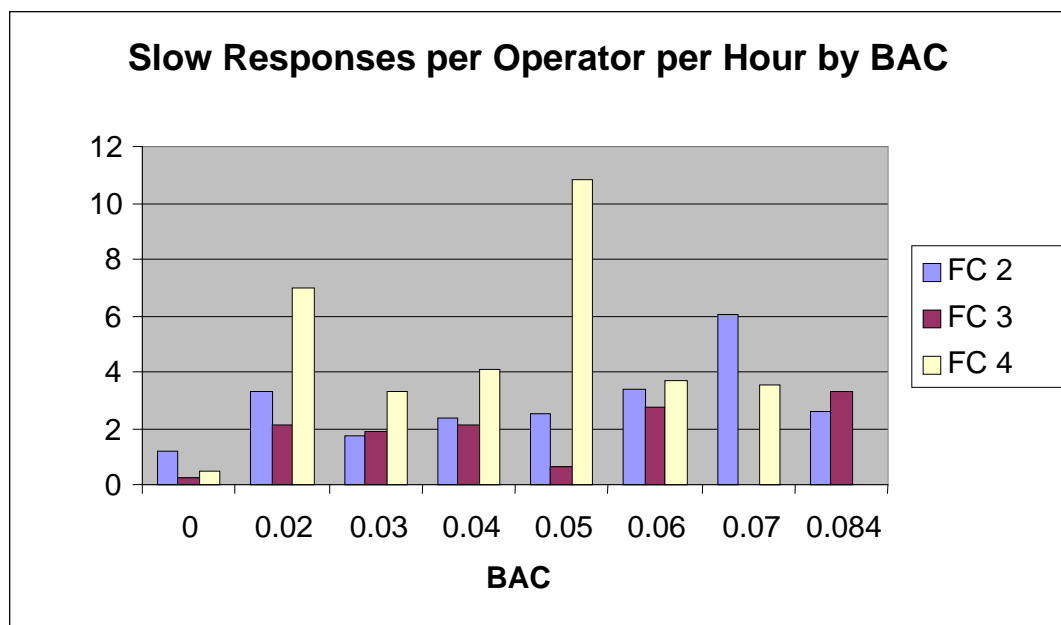


Figure 26: Slow performance responses by BAC.

Figure 26 shows all slow responses that were recorded during the alcohol treatment sessions. An FC 2 response is one standard deviation (SD) slower than baseline, an FC 3 is two SD slower than baseline and an FC 4 response is one indicating three SD slower than baseline responses. Of these measures, the extreme responses tend to reflect the general results of all errors and slow responses as shown in Figure 25. Again, there is a sudden increase at 0.02% BAC, which then decreases and rises again at 0.05% BAC.

The following figures (Figure 27 and Figure 28) illustrate the different performance patterns due to alcohol intoxication between an early night (2000 hrs – 2200 hrs) and a late night (2200 hrs – 0000 hrs). The responses in the early session indicate that subjects are quite affected at 0.02% BAC but are able to recover from 0.03% BAC to 0.04% BAC. At 0.05% BAC and above, most subjects are not too capable of responding quickly at all.

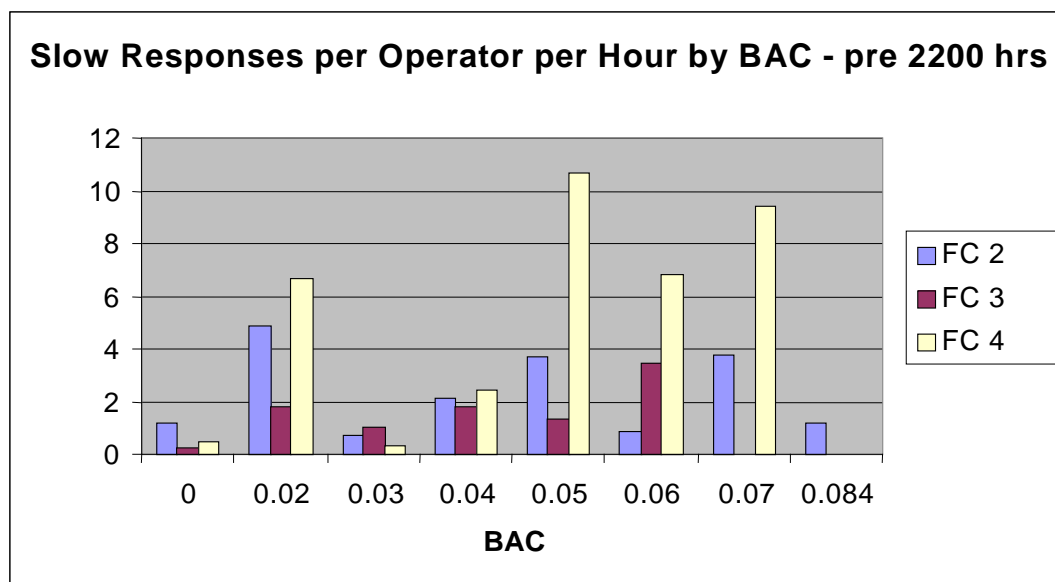


Figure 27: Slow performance responses between 2000 hrs and 2200 hrs.

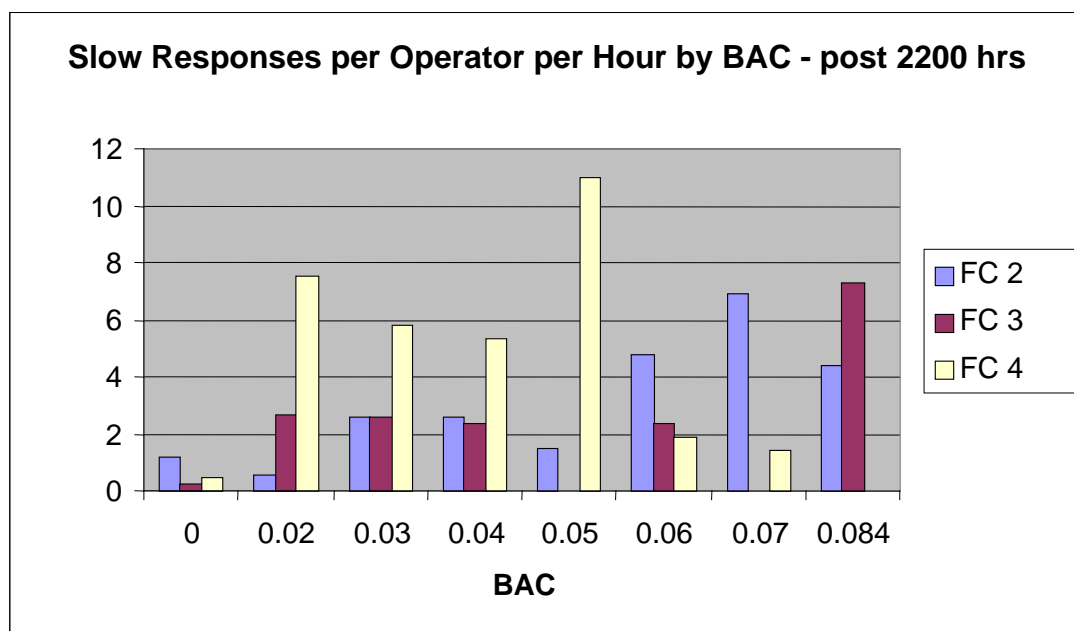


Figure 28: Slow performance responses between 2200 hrs and 0000 hrs.

It is interesting to note that after 2200 hrs, most subjects show performance decrements between 0.02% BAC and 0.05% BAC. It could be argued that most subjects tend to be affected by both the alcohol and time of day effects. It appears that even light levels of intoxication have detrimental effects later during the night.

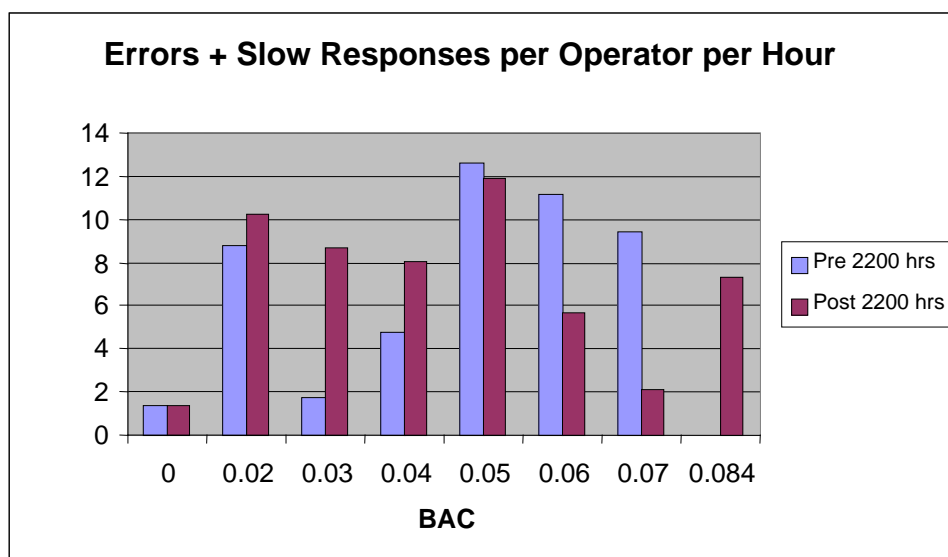


Figure 29: Comparative performance effects of alcohol pre- and post- 2200 hrs.

Figure 29 shows the disparity between the two alcohol sessions. The results for all errors and slow responses indicates that performance is not as poor early in the night unless a reasonably high BAC is reached (after the initial 0.02% BAC). However, later at night, performance is seriously affected by low levels of BAC.

4.2.1 Summary of Alcohol and Reaction Times

The first question to answer regarding alcohol and reaction times is whether or not the ARRB FMD can detect performance decrements due to alcohol intoxication. Clearly, this is the case. The fact that on 26 out of 27 occasions the driver stated they would hand over their keys and not drive at 0.02% BAC, adds much face validity to the use of the device as a performance measure.

There are clear performance effects shown at 0.02% BAC, both from errors and very slow responses. Transferred to a mining environment, such slow responses could result in many incidents and accidents. This being the case, it is recommended that mines adopt a policy of setting alcohol tolerance levels to 0.02% BAC or less. It would be hard to justify a higher tolerance level in the face of such data.

5 Conclusions

The findings of this research study are of significant importance to the mining industry. It is said to be the first real set of objective data presented to the Australian mining industry that has been taken from within the industry itself. It is a large amount of data (3,200 + hours), which lends itself to scientifically valid interpretation. It would be wise to continue gathering such data at every opportunity to help in the continuing determination of ways to manage fatigue and performance.

It can be argued that for a single night of driving haul trucks, there appears to be no affect on fatigue from the amount of time on task (for the 12 hours). The circadian influence had a stronger affect than working more than eight hours.

Of the fourteen nights worked at the site, nights thirteen, fourteen, seven and two respectively, were the worst. This presents a conundrum for policy makers who may like to place caps on working hours or rosters in the hope that it will alleviate the fatigue issue. It will not. The major finding within this study is the combined influence of circadian rhythms and individual variability. The lifestyle habits and the health of individuals have a profound effect on operator performance as shown by the strong positive correlation between high fatigue risk scores and poor performance. An individualistic approach would appear to have the best chance of reducing high potential incidents due to fatigue through successive nightshifts.

The ARRB FMD has been shown to be very good at measuring reduced driver performance due to alcohol intoxication. The FC 4's used as measure of high potential incidents within the study, are found at blood alcohol concentrations of 0.02%. This adds strong support for setting alcohol tolerance levels at 0.02% BAC for the mining industry, as the corresponding level of performance can be considerably poor for some drivers.

Similarly, if the ARRB FMD technology is utilised within any mining situation, there is strong evidence that the parameters of FC 4's equates to the performance of drivers with a blood alcohol concentration of between 0.02% BAC and 0.05% BAC.

5.1 Recommendations

The findings clearly indicate that placing limits on successive nightshifts will not in itself alleviate the fatigue problems that are present during nightshift operations. In fact it could be argued that people may rely on limits to avoid the consequences of fatigue, rather than investigating other causal factors. The data collected from the fatigue monitoring devices, together with the fatigue risk scores and anecdotal evidence, create a strong case for arguing that each operator takes to work health and lifestyle issues that impact on their subsequent performance. This is then compounded by circadian influences through the circadian trough (midnight to dawn), but may also manifest itself through other parts of the evening that are normally considered as a 'high arousal' period.

It would be wise to continue gathering such data at every opportunity to help in the continuing determination of ways to manage fatigue and performance. The current data has been obtained from a fly-in, fly-out site, whereby operators get adequate opportunity to obtain restorative sleep between shifts. Data needs to be captured from other sites that have nearby community living and fewer shifts for which to compare the data. This will assist to develop a more reasoned understanding of the number of successive nightshifts before performance begins to deteriorate below acceptable safety levels. Until such time, operators should be viewed as individuals and it should be accepted that their performance will vary from other operators and at different times of the day/night. This will not be managed by limits on operations.

5.2 Acknowledgments

Coal Services (Health & Safety Trust) are kindly acknowledged for their funding and support of this very important research. This research has made an important inroad into how the mining industry might best formulate fatigue management plans and strategies.

Kind acknowledgments are also forwarded to Sons of Gwalia and MacMahons who provided the site, haul trucks, operators and assistance throughout the trial. Finally, the 24 operators who put more than 3,500 hours into operating machinery with the ARRB FMD technology in place. It is hoped that they feel they contributed to a very important cause – their own!

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Appendix 1 – Consent Form

Driving simulator research consent form

13 January 2003

Driving simulator research

In conjunction with Assoc. Prof. Hartley, I am about to commence research involving driving whilst intoxicated on the driving simulator at Murdoch University. Subjects will be required to drive for a two-hour no treatment session, followed by two, two-hour alcohol treatment sessions. Each subject will receive reimbursement of the equivalent of one-day casual wage (\$120.00 less tax) for undertaking the trials. As you can imagine, strict criteria will apply to the selection of subjects for the trial, due to the risks associated with intoxication. This consent letter is to indicate that you have agreed to undertake this study acknowledging that to the best of your knowledge you meet the following criteria:

- 1 That you are not currently taking prescription or social drugs;
- 2 That you have never suffered head trauma;
- 3 That you have never presented with a psychological or psychiatric illness;
- 4 That you are not currently undergoing medical treatment for anything;
- 5 That you have no known medical conditions at all (eg. high blood pressure, diabetes, heart problems, etc), that may place you at any risk if you undertake the study, and
- 6 That you have never presented, or suffered from an alcohol dependency.

All information relating to subjects will be kept strictly confidential and personal results will not be made available to anyone including the subjects. You may wish to pull out of the study and may do so at any time without prejudice. You may also wish to contact Assoc. Prof. Hartley on 9360 2398 or myself on 9227 3000 if you require any further information.

Yours sincerely,

Nick Mabbott
Ph.D candidate
Senior Research Scientist,
ARRB Transport Research Ltd.

Subject

Please sign

Please print

Date

Appendix 2 – Calibration Report

TR3a Version1

Breath Analysis Section
2-4 Wellington Street
East Perth WA 6004
Tel: 08 9222 1518
Fax: 08 9222 1506



WESTERN AUSTRALIA POLICE SERVICE

CALIBRATION REPORT

FOR: Murdoch University

MANUFACTURER: Lion Laboratories Limited

TYPE: Alcolmeter SD2

SERIAL NUMBER: 007718

DATE OF TEST: 6th January 2003

The instrument was calibrated on a Alcotest AR200C equilibrator Serial Number 96001 using a certified 0.100% ethyl alcohol solution heated to $34^{\circ}\text{C} \pm 0.1^{\circ}\text{C}$.

The instrument was calibrated to indicate a result of 0.100 grams of alcohol in 100 millilitres of blood \pm 0.005 grams of alcohol in 100 millilitres of blood.

A handwritten signature in black ink, appearing to be 'G J Hay'.

G J HAY
Senior Constable
Technical & Training Unit
Breath Section