COMPARISON OF WORKSHIFT PATTERNS ON FATIGUE AND SLEEP IN THE PETROCHEMICAL INDUSTRY

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Introduction

Petrochemical industry has high prevalence of 24/7 shiftwork

- 4 crew, 12 hour patterns are most prevalent
- Historically no Hours of Service (HoS) requirements or recommended practices

2005 BP Texas City Explosion

- Chemical safety board (CSB) cited fatigue as a contributing causal factor
- Recommended development of industry wide integrated Fatigue Risk Management Program (FRMS)

2010 American Petroleum Institute issues RP-755: FRMS for Personnel in the Refining and Petrochemical Industries.

- RP-755 includes Hours of Service (HoS) Limits
- 12 hour shifts:
  - 7 during normal operations
  - 14 during outages

Introduction

Studies on the effects of consecutive work days have sometimes shown contradictory results.

- While the effects of long number of consecutive shifts (7, 14 and greater) have been well studied in the off-shore industry and remote locations, there are few studies evaluating these shifts in **commuter operations**.

Introduction

Purpose of this study was to investigate two different 12-h rotating shift schedules

- one with 7 consecutive night shifts
- another with 14 consecutive night shifts in a commuter operation

to further understand the effects of the work pattern of petrochemical shiftworkers on sleep and fatigue.

Methods –Subjects and Schedule

Subjects

- 24 refinery operators
- 37 years old average
- All male

Schedules

- Days on/off pattern:
  - **Schedule 1**: 7D, 7 off, 7N, 7 off
  - **Schedule 2**: 14N, 7 off, 7D, 14 off, 7D, 7 off
- Shift start times: 5 am and 5 pm for both schedules
- Both studies conducted during Normal Operations
- Subjects received sleep / shiftwork lifestyle training prior to first study

Methods - Protocol

- Operators worked both schedules for complete schedule cycle (Schedule 1: 28 days, Schedule 2: 56 days)
- Participants completed duty/sleep logs and wore an actigraph (ActiLife) every day during both schedule cycles
- On work days, participants completed sleepiness/fatigue assessments and a performance test at the beginning and the end of their shifts
- The analysis included:
  - Comparison of average values in both schedules
  - Evolution of the parameters across consecutive shifts
- Statistical analyses were conducted using paired t-tests.

Methods - Measurements

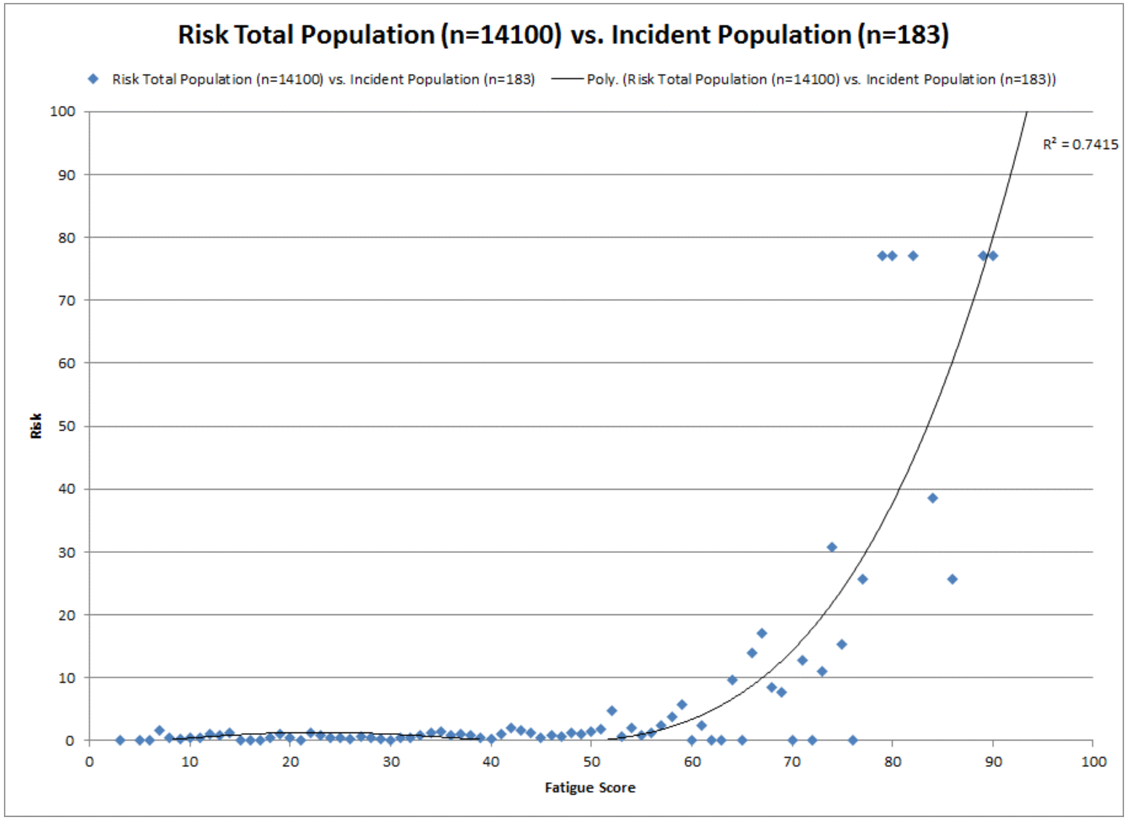
- **Sleep duration** assessed using both daily sleep/duty logs and actigraphy.
- **Overall fatigue score during the cycle** assessed using the scientifically validated fatigue model CAS (Circadian Alertness Simulator).
- **Subjective sleepiness** measured using a Visual Analog Scale
- **Subjective fatigue** measured using the Samn-Perelli scale
- **Performance** evaluated using a 3-min version of the Psychomotor Vigilance Task (PVT)

Methods – CAS fatigue modeling

- CAS-5 is based on the laws of circadian & sleep physiology
- Uses a three-process model to compute alertness which combines:
  - **homeostatic factors** (build up of sleepiness during wakefulness and dissipation during sleep)
  - **circadian factors** (the phase of the human biological clock and its adjustment to time zones or night work)
  - **sleep inertia** (the transitory impairment of alertness on arousal from sleep depending on circadian phase, length of sleep and level of prior sleep deprivation)
- CAS has been progressively optimized for over 20 years using large populations of equipment operators where sleep and alertness on duty has been simultaneously measured, including 10,000 hours side by side EEG & CAS analysis
- Utilizes actual sleep when data is available and predicts it when it is not

Methods – CAS fatigue modeling

CAS fatigue risk scores were calculated using actual work and sleep hours. CAS classifies fatigue risk in three fatigue levels: low (0-30), average (31-60), high (61-100). In shiftwork operations the rate of human error accidents starts climbing exponentially once CAS Fatigue Risk Score exceeds 60.

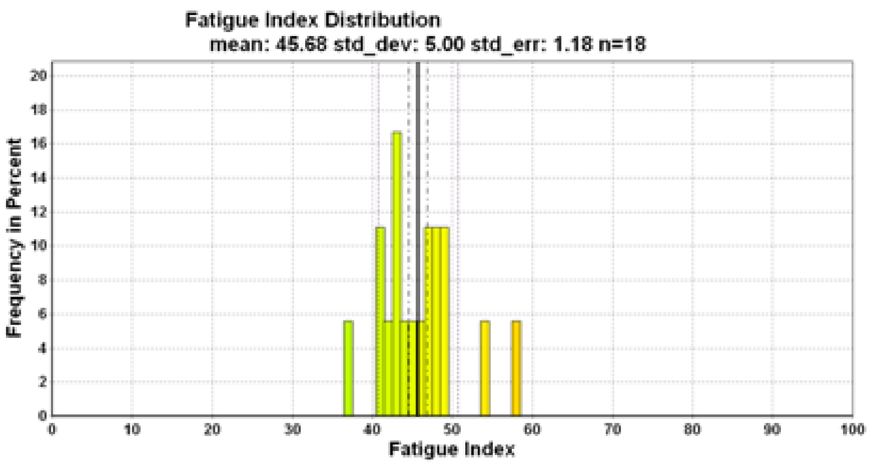


Results – CAS Fatigue Score

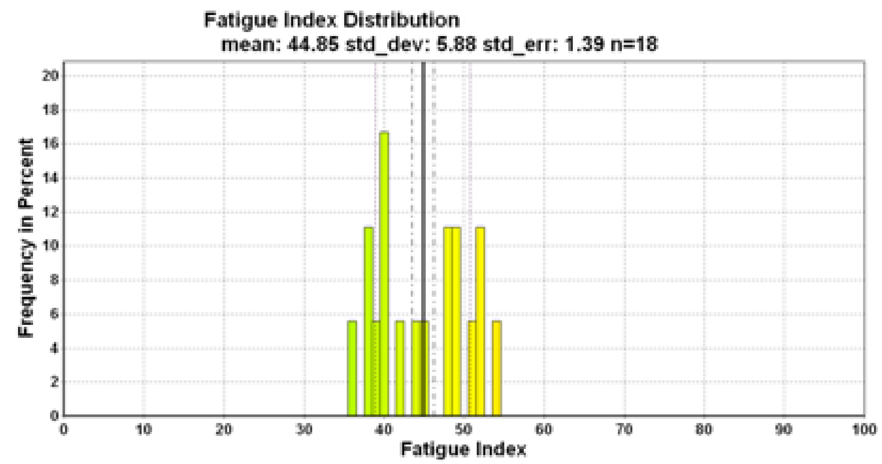
The overall fatigue score was similar in both schedules :

- Schedule 1 (7 on, 7 off): 45.7
- Schedule 2 (14N-7 off, 7D-14 off, 7D-7): 44.8

Schedule 1: 7 on, 7 off



Schedule 2: 14N-7 off, 7D-14 off, 7D-7



Summary of results

	7 on, 7 off		14N-7 off, 7D-14 off, 7D-7 off	
	Day Shift	Night Shift	Day Shift	Night Shift
Sleep (logs)	6h 21 min	6h 43 min	6h 40 min	6h 56 min
Sleep (actigraphy)	6h 32 min	6h 47 min	6h 26 min	6h 55 min
Sleep before 1st D	6h 17 min		5h 43 min	
Sleep before 1st N		9h 26 min		10h 04 min
Sleepiness (VAS)	26.5	31.3	17.1*	18.8*
Samn-Perelli	2.6	2.9	1.9*	2.1*
PVT Median RT	230.8	225.4	222.2	221.3
Fatigue (CAS)	45.7		44.8	

Visual Analog Scale (VAS): 0=very alert, 100 = very sleepy.
Samn-Perelli: 1) ‘fully alert, wide awake’; 2) ‘very lively, responsive but not at peak’; 3) ‘OK, somewhat fresh’; 4) ‘a little tired, less than fresh’; 5) ‘moderately tired, let down’; 6) ‘extremely tired, very difficult to concentrate’; 7) ‘completely exhausted, unable to function effectively’.

* significant difference between schedules

Results – Average sleep duration

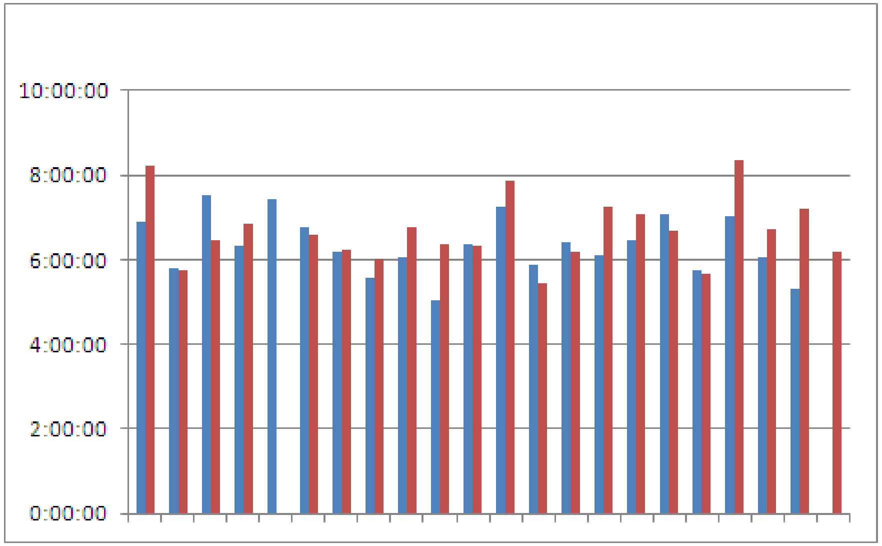
Sleep/work logs data:

- Day shift: operators slept more on Schedule 2 (6h 40 min) than on Schedule 1 (6h 21 min), p<.05
- Night shift: no significant difference between schedules (Schedule 1: 6h 43 min, Schedule 2: 6h 56 min)

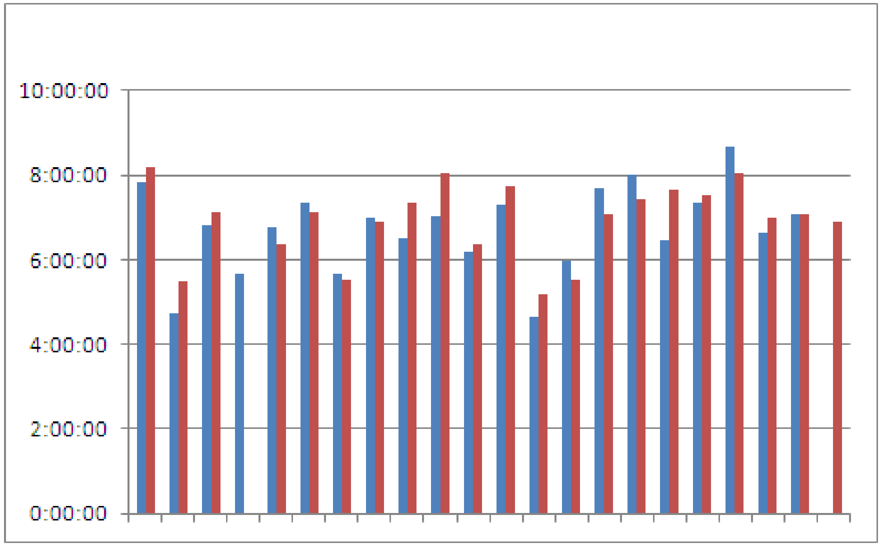
Actigraphy data:

- Day shift : Schedule 1: 6h 32 min, Schedule 2: 6h 26 min, NS
- Night shift: Schedule 1: 6h 47min, Schedule 2: 6h 55 min, NS

Day shift



Night shift



Average sleep duration by operator. Sleep/work logs data.

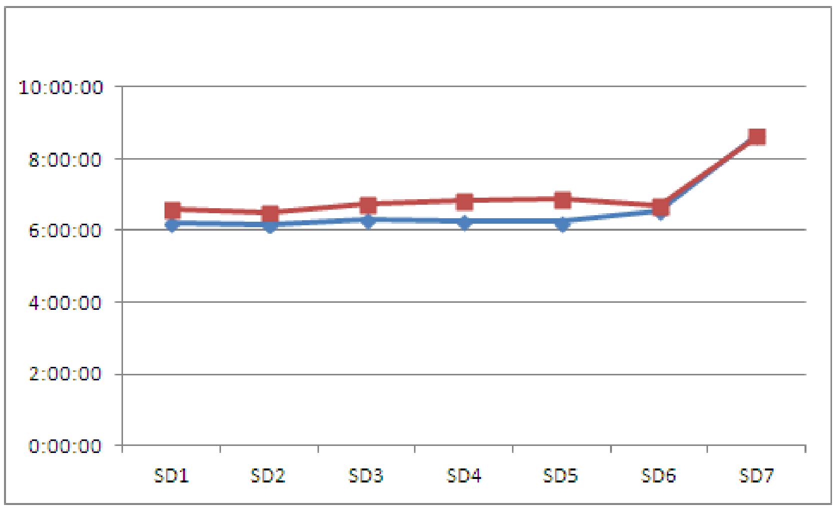
Schedule 1: 7 on, 7 off   Schedule 2: 14N-7 off, 7D-14 off, 7D-7

Results –Sleep by consecutive shift

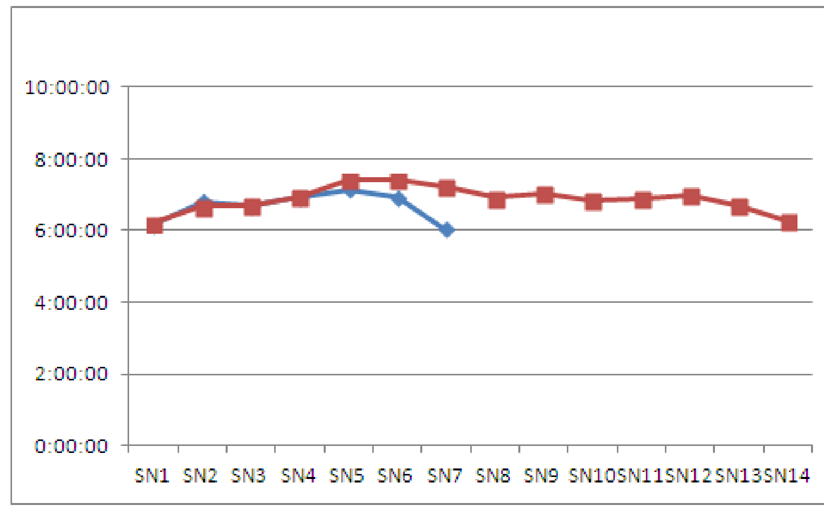
Day shift: the amount of sleep between consecutive shifts remained quite similar across shifts for both schedules

Night shift: sleep duration was slightly shorter during the first 2-3 nights and during the last couple of nights for both schedules.

Day shift



Night shift



Sleep by consecutive shift. Sleep/work logs data.

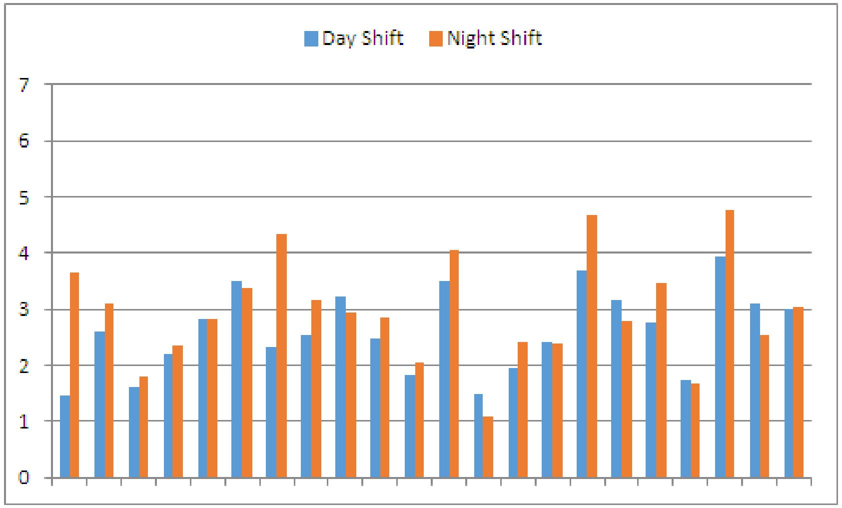
Schedule 1: 7 on, 7 off

Schedule 2: 14N-7 off, 7D-14 off, 7D-7

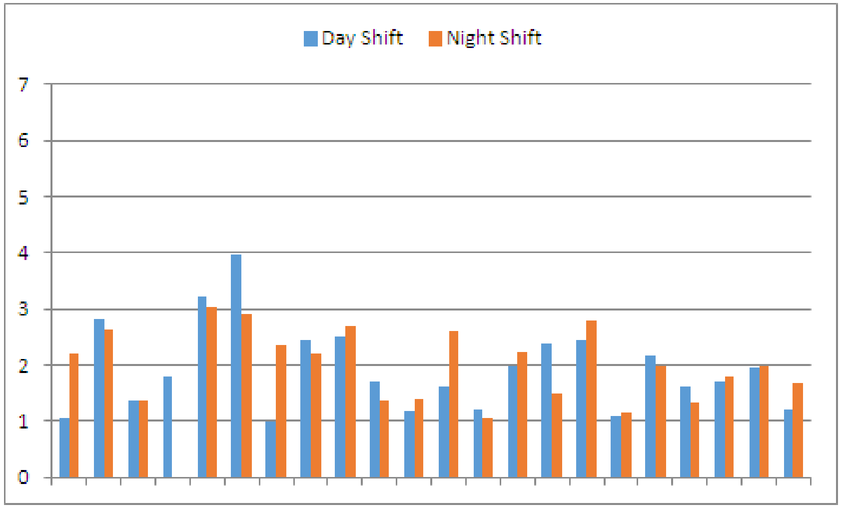
Results –Average Subjective Fatigue

Average fatigue was significantly higher in Schedule 1 than in Schedule 2, both during day shift (2.6 vs. 1.9) and night shift (2.9 vs. 2.1) (p<.05).

Schedule 1: 7 on, 7 off



Schedule 2: 14N-7 off, 7D-14 off, 7D-7

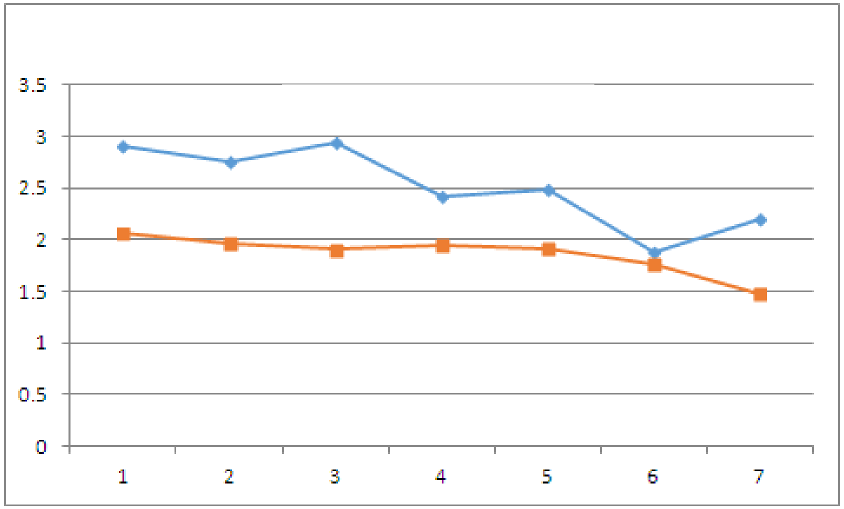


Fatigue scores by operator (Samn-Perelli).

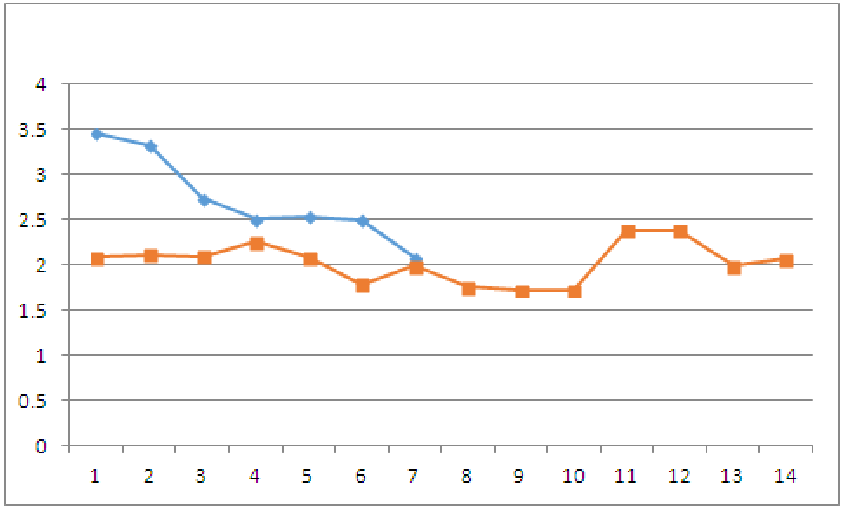
Results –Subjective Fatigue by consecutive shift

Subjective fatigue did not increase linearly with consecutive shifts.

Day shift



Night shift



Subjective sleepiness by consecutive shift (Samn-Perelli)

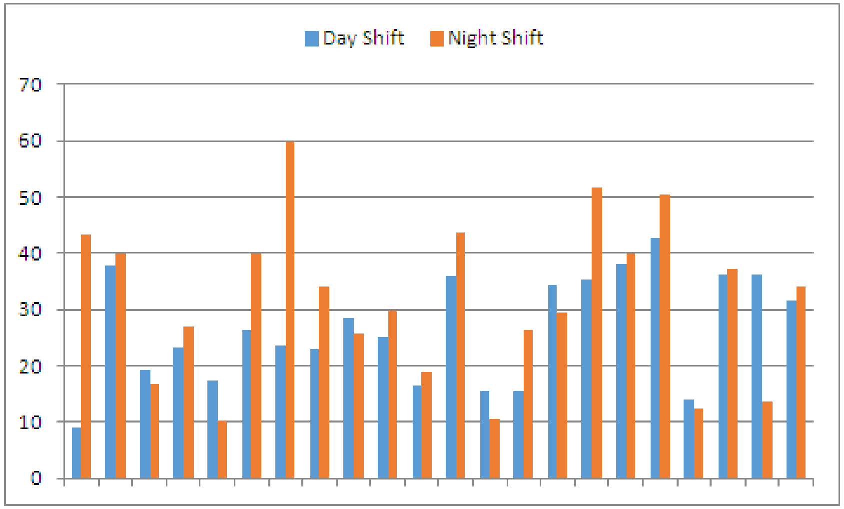
Schedule 1: 7 on, 7 off

Schedule 2: 14N-7 off, 7D-14 off, 7D-7

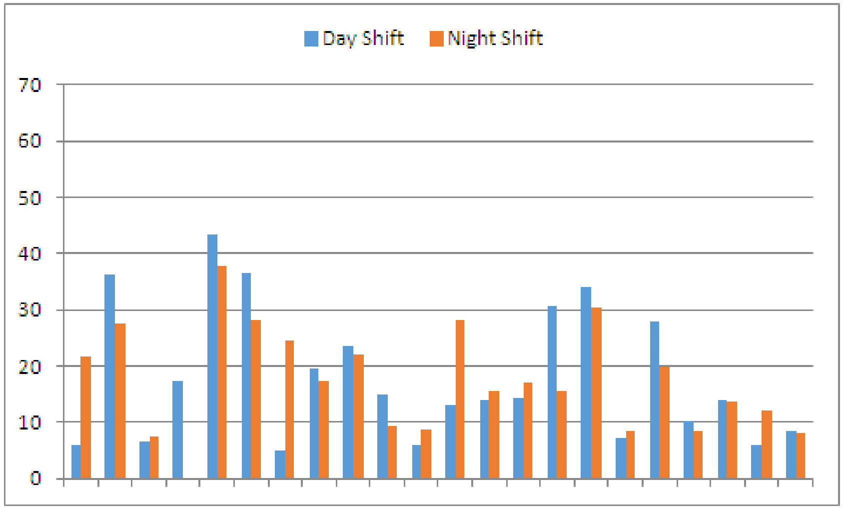
Results –Average Subjective Sleepiness

Subjective sleepiness was significantly higher in Schedule 1 than in Schedule 2, both for the day (26.5 vs. 17.1) and night shift (31.3 vs. 18.8) ($p<.05$).

Schedule 1: 7 on, 7 off



Schedule 2:14N-7 off, 7D-14 off, 7D-7

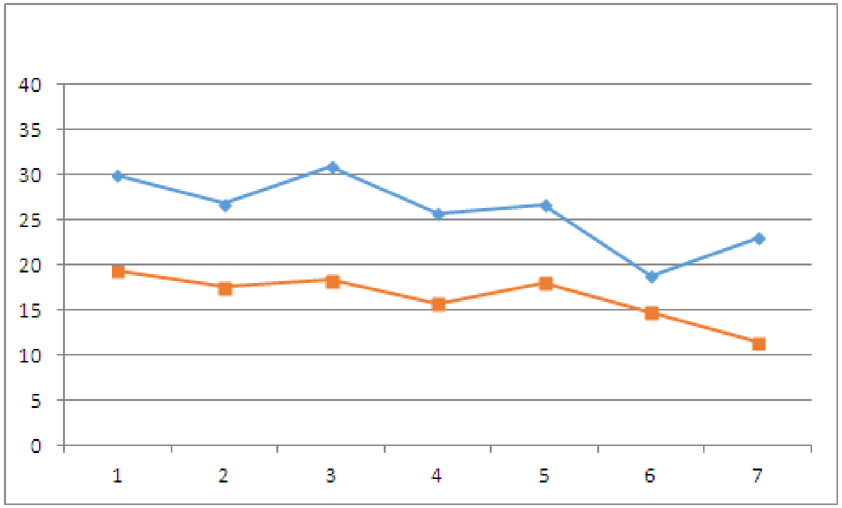


Sleepiness scores by operator (VAS)

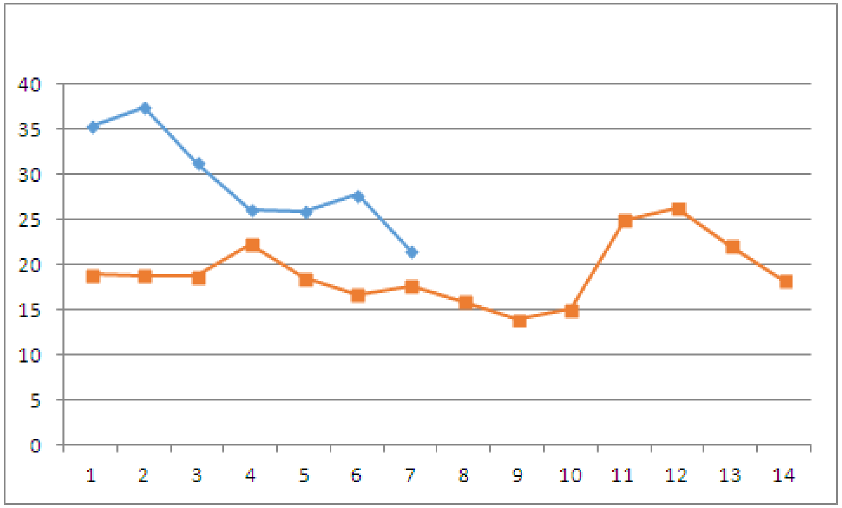
Results – Subjective Sleepiness by consecutive shift

Subjective sleepiness did not increase linearly with consecutive work shifts.

Day shift



Night shift



Subjective sleepiness by consecutive shift (VAS).

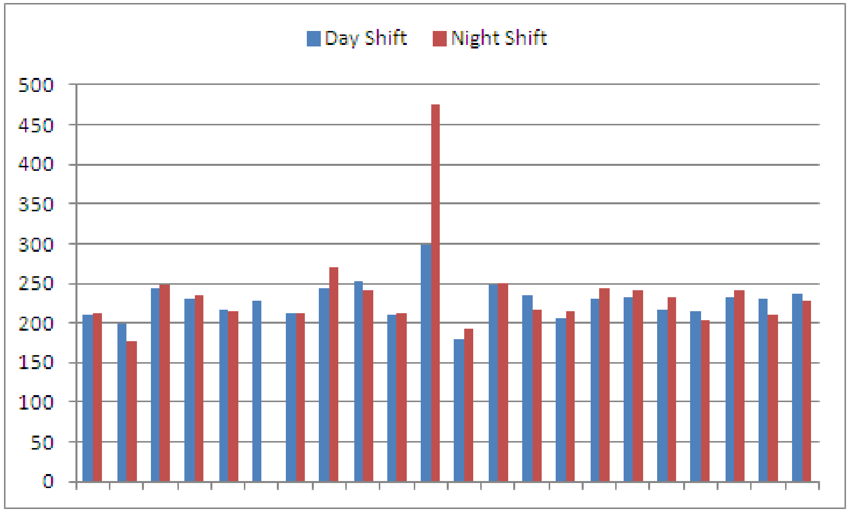
Schedule 1: 7 on, 7 off

Schedule 2: 14N-7 off, 7D-14 off, 7D-7

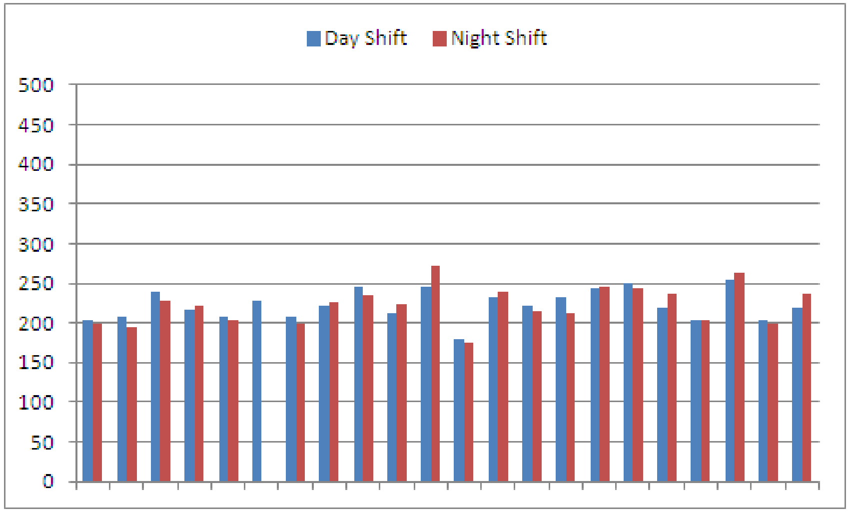
Results – Average Performance (PVT)

Average performance was similar for schedule 1 and schedule 2 for both day shift (230.8 vs. 222.2) and night shift (225.4 vs 221.3).

Schedule 1: 7 on, 7 off



Schedule 2: 14N-7 off, 7D-14 off, 7D-7

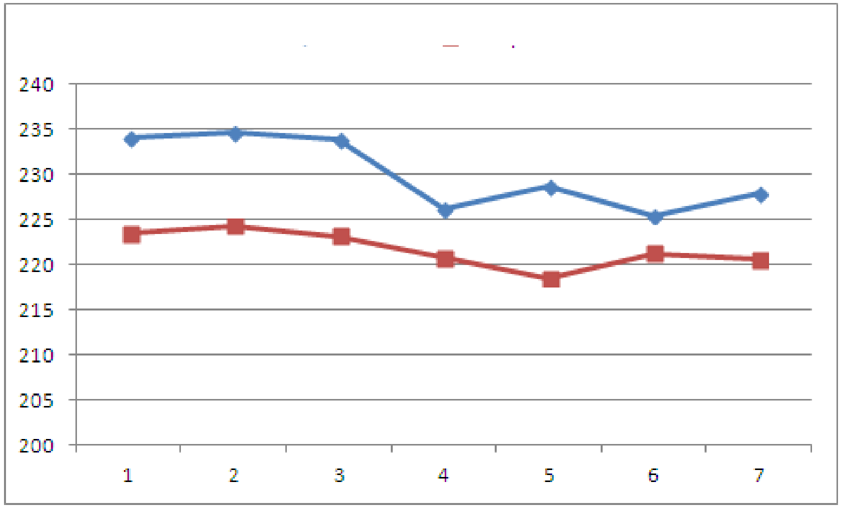


Performance by consecutive shift: PVT – Median RT (ms).

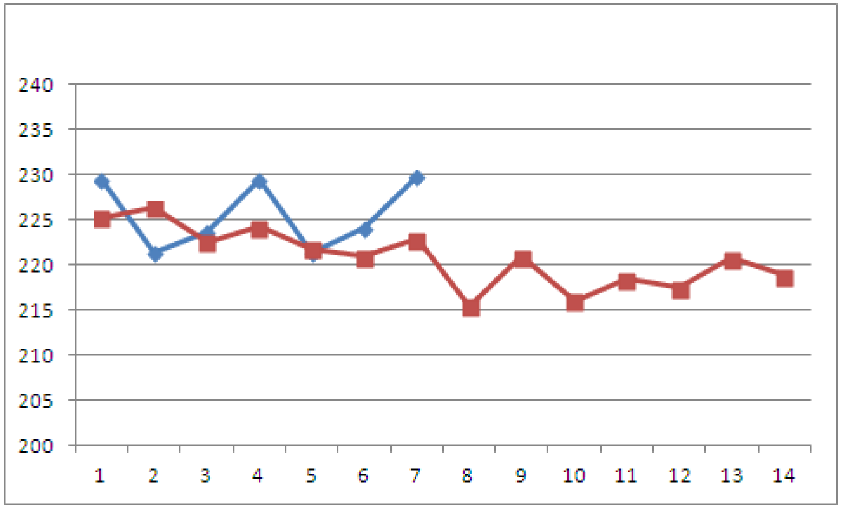
Results – Performance by consecutive shift

Performance did not decrease linearly with consecutive work shifts.

Day shift



Night shift



Performance by consecutive shift: PVT – Median RT (ms).

Schedule 1: 7 on, 7 off

Schedule 2: 14N-7 off, 7D-14 off, 7D-7

Discussion and Summary

- No evidence of increased fatigue while working a schedule with 14 consecutive night shifts compared to 7 consecutive night shifts.

- Sleep and alertness were not negatively impacted by working more shifts.

- The sleep duration across consecutive night shifts is in agreement with other studies suggesting that the first night shifts are the most difficult.

Discussion and Summary

- Our findings are consistent with studies conducted in remote locations:

  - with appropriate environmental conditions, workers adapt to extended blocks of night shifts.

  - as long as adequate sleep is obtained a greater number of consecutive shifts does not have a significantly negative impact on fatigue.

Discussion and Summary

- Our findings are consistent with studies that show that fewer circadian transitions result in decreased sleepiness and fatigue.

- It should be noted the 14 consecutive night shift schedule was proposed by employees, which may have affected the results. It would be important to re-evaluate the schedule after operators have worked it for a longer period of time.

- Schedules with long work blocks should only be implemented in the context of a comprehensive FRMS.

Questions?

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