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

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Introduction: The petrochemical industry is characterized by a high prevalence of shiftwork that operates using a number of different schedules. Historically, efforts to mitigate fatigue in 24/7 operations have focused on setting Hours of Service (HoS) limits (shift duration, consecutive work shifts, and maximum amount of work hours in a given period). Recently, there has been a trend to integrate HoS into a more comprehensive fatigue mitigation approach, a Fatigue Risk Management System (FRMS). The American Petroleum Institute developed in 2010 the RP-755 for a FRMS for Personnel in the Refining and Petrochemical Industries. RP-755 addresses and mitigates the inevitable risks associated with night work and changing work/sleep patterns on sleep quality and duration, fatigue, and performance. 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. The purpose of this study was to investigate the effects of two different 12-h rotating shift schedules, one with a maximum of 7 consecutive shifts and another with a maximum of 14 consecutive shifts to further understand the effects of the work pattern of petrochemical shiftworkers on sleep and fatigue.

Methods: Twenty-four refinery operators (37 years old average, all male) participated in the study. The operators worked two different shift patterns, each one for a complete schedule cycle. Schedule 1 was a standard 7 on, 7 off schedule (7D, 7 off, 7Night, 7 off); Schedule 2 was a 14N-7 off, 7D-14 off, 7D-7 off schedule (D=Day, N=Night). Both schedules had shift start times of 5 am and 5 pm. Participants completed daily sleep/duty logs and wore an actigraph during the complete schedule cycle. Sleep duration was assessed using both subjective (daily log) and objective (actigraphy) data. Activity data was processed using ActiLife software. On work days, subjective sleepiness (Visual Analog Scale) was also measured. Fatigue was assessed using the scientifically validated fatigue model CAS (Circadian Alertness Simulator), based on the laws of circadian and sleep physiology. CAS fatigue risk scores were calculated using duty hours and actual time asleep. CAS classifies fatigue risk in three fatigue levels: low (0-30), average (31-60), high (61-100). In addition to the overall fatigue score, CAS calculates alertness levels. Alertness is scored on a scale from 0 to 100 (0=very alert, 100= very sleepy). Statistical analyses were conducted using paired t-tests.

Results: Sleep: In Schedule 1, sleep duration was similar while working day and night shift, while in Schedule 2 there was a trend to a longer sleep while working night shift than day shift. Based on duty/sleep logs, while working day shift, operators slept more while working Schedule 2 (6h 40 min) than on Schedule 1 (6h 21 min), $p<.05$. There was no significant difference in sleep duration between schedules while working night shift (Schedule 1: 6h 43 min, Schedule 2: 6h 56 min). Overall, actigraphy data support log data and sleep duration on day shift was not statistically different in both schedules (Schedule 1: 6h 21 min vs. Schedule 2: 6h 51 min). Most operators prepared for the first night shift by taking a nap before the shift, and consequently total sleep during the 24 hours before the first night shift was significantly more than during the 24 hours before the first day shift (Schedule 1: 6h 17 min vs.

9h 26 min, Schedule 2: 5h 43 min vs. 10h 04 min), p<.001. On both schedules, while working night shifts, sleep duration was slightly shorter during the first 2-3 nights than during the rest of the consecutive night shifts. On Schedule 2, sleep was shorter after the first night shift, increased during the first week of consecutive shifts and then decreased slightly and remained at a similar level during the second week of night shifts.

Sleepiness and fatigue: The overall CAS fatigue score was similar in both schedules: 45.7 for Schedule 1 (7 on, 7 off) and 44.8 for Schedule 2 (14 consecutive N shifts). Both schedules were below the threshold (60 score) associated with an increased accident risk. CAS alertness score was similar for both schedules during day shift, but was higher for Schedule 2 than for Schedule 1 during night shift (50.2 vs 47.9, p<.05). 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) and did not increase linearly with consecutive work shifts.

Discussion: Our results did not show evidence of increased fatigue while working a schedule with 14 consecutive night shifts compared to 7 consecutive night shifts, and sleep and alertness were not negatively impacted. The sleep duration across consecutive night shifts is in agreement with other studies suggesting that the first night shifts are the most difficult. Studies conducted in remote locations and off-shore facilities have shown that, given the appropriate environmental conditions, workers adapt to the extended blocks of night shifts and as long as they obtain adequate sleep a greater number of consecutive shifts does not have a significantly negative impact on fatigue. Our findings are consistent with studies in the petrochemical industry that suggest that perhaps a schedule with fewer circadian transitions between nights and days is associated with decreased sleepiness and fatigue. However, it should be noted that Schedule 2 (with 14 consecutive night shifts) was an alternative schedule proposed by employees which may have affected the results. Also, these kinds of schedules should only be implemented in the context of a comprehensive FRMS. It would be important to re-evaluate the schedule after operators have worked it for a longer period of time, to ensure that they still obtain adequate sleep, and fatigue and alertness remain at an adequate level. **Summary:** In this study, compared to a 7 on-7 off (schedule 1), working a 14N-7 off, 7D-14 off, 7D-7 off (schedule 2) was not associated with an increase in fatigue amongst refinery operators in a petrochemical commuter operation, in fact, operators on schedule 2 slept longer and had lower subjective sleepiness scores then operators on schedule 1.