Shift-working offshore: roll-over vs. permanent nights

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Abstract

This paper explains the UK HSE regulatory position with regard to shift-work and the need for shift-work to become part of the risk management process. Advances in research understanding are reviewed and the growing evidence for the adjustment of offshore workers to continuous night shifts is discussed. Data is presented to demonstrate the significant effects of shift-work and fatigue on accident rate. The problem of preferred vs. safest shift patterns is discussed and suggestions made as to how this problem may be addressed.

Introduction

It is the mission of the HSE to "ensure that risks to people's health and safety from work activities are properly controlled". Historically risk control has been interpreted as a technical and engineering activity with the focus on maintaining the safe operational performance of plant. In recent years the introduction of formal Safety Management Systems (SMS) has shifted attention to the manner in which the operation of the hazardous plant is managed, including the accountabilities for risk and the chain of responsibility. The disciplines of Human Factors (HF) and Occupational Health (OH) have tended to exist separately to the engineering and management approaches to hazard control. The HF approach has tended to address the human / machine interfaces and usability while the occupational health practitioners have monitored exposure to physical challenges and provided support in the event of injuries and ill health.

The maintenance of the performance of the human operators to mitigate the detrimental effects of fatigue due to long hours, night work, shift changes or heavy work loads has by and large been neglected. If safety and operational performance are to improve from the current position than this situation cannot be allowed to continue. There is widespread recognition that the human operator, maintenance worker or drill floor worker is a key part of the offshore technology and, when the technical safety systems have failed, the final protection barrier against a major disaster.

One reason for the omission of the offshore industry to address the performance of their human resources and control the risks posed by fatigue may be that hither to that risk has not been quantified. The offshore industry is not alone in that, indeed it is only in the past year that research has shown that fatigue may now be causing more road deaths in the UK can alcohol[i]. A reanalysis of past aviation accidents by NASA has identified fatigue as the most commonly reported secondary cause of accidents[ii]. Previous analyses of this data have only included the primary cause. One way of interpreting this finding is to conclude that in many of these incidents the pilot's ability to recover the from a high risk situation or mechanical failure was impaired by fatigue to the extent that recovery was not undertaken successfully.

The concept that fatigue impairs the human operator's ability to recover from a hazardous situation is an important one as it provides one explanation for an event which has historically been a near miss turning into an accident. In the Reason "Swiss cheese" model[iii] the human operator forms one of the safety barriers that have to be maintained intact if potential accident causing situations are to be prevented from causing the accident. In this model fatigue can be modelled as causing a hole in the human attention and performance barrier.

Analyses of all reported accidents on the UK continental[iv] shelf shows a highly significant relationship between accidents and a range of temporal factors including time of day and time into tour. If the accident rate during the period of peak likelihood could be reduced that of to the minimum likelihood period then very significant improvements in safety would result. This remains true even after the best attempts are made to correct these distributions for variations in workload due to seasonal activities or day only activities. In the case of the rise in serious accidents during the third week offshore (see below) the figures must be adjusted for the reduced proportion of the UK workforce working the third week offshore. This sharp increase in risk in the third week has previously been masked by the failure of analysts to apply this correction and has lead to the misperception that the constant accident rate over the three weeks means constant risk. In reality the reduced numbers working means that the risk of serious injury has risen by over 40% in the third week[v].

The role of the Health and Safety Executive

As the UK regulator for offshore safety, the HSE does not explicitly regulate shift work. We may become the enforcing body for the European Union Working Time Directive when this comes into force offshore but the Directive is primarily concerned with maximum working hours and annual leave and is unlikely to address the complexities of scheduling offshore work safely. The HSE does however regulate health and safety and we actively seek to combine this regulation maintenance or improvement of industry performance wherever possible. We operate within a legal architecture with a hierarchy of instruments:

1 the Health and Safety at Work Act 1974
2 Regulations
3 Approved Codes of Practice (ACoP)
4 Guidance
5 (Research)
6 Information

Note: “research” is in parentheses because it is an *informal* part of the framework.

The higher in the list the instrument is, the harder it is to change. In an area like shift working where understanding is limited research plays the major role, followed by the provision of information. If a robust understanding of the risk control measures has been achieved this may extend to guidance or an ACoP. What we will do is extend the interpretation of the existing legal framework requiring risk assessment, control of risk and safety management systems to include fatigue and the scheduling of work. Our goal is to see that fatigue becomes a normal part of the risk assessment process and is managed as part of the SMS along with the other potential hazards identified by that risk assessment.

Why shiftwork?

There are important reasons why shiftwork and fatigue should be addressed now. Shift working and 12 hour days and nights impinge on the health and safety of virtually every person working offshore so small improvements have the potential bring large overall gains. The offshore shift patterns of extended periods of 12 hour days or nights are almost unique to the industry and yet have not been included in the other assessments of unique risks. There is no scientific justification for the wide diversity in shift patters currently operating offshore and it is therefore very unlikely that all are equally effective in performance or safety terms or equally “fit for purpose”. As our understanding of the issues increases there is evidence to suggest that advice regarding shift working derived from onshore experience is at best inappropriate and at worst dangerous, when applied offshore. Finally the 12 hour by 14 to 21 day tour requires a minimum continuous working period of 84 hours, far more than any other industry and a potential target for these outside the industry who may wish to make political capital out of enforcing the Working Time Directive.

There are a number of constraints that limit the extent of any changes that could be made to offshore working patterns. The first among these is that there will normally be 2 x 12 hours work periods so that 24-hour cover requires no more than two workers. Any attempt to change this would be counter to the need to reduce the numbers exposed to hazard, the economic pressure to reduce crew sizes, and the difficulty of providing increased accommodation offshore. While travel to and from offshore installations is by helicopter then the helicopter load factors and schedules will constrain tour patterns. There are also a number of other constraints that will have to be overcome, for example resistance to change and remuneration systems based around inappropriate work schedules. We do not however judge these difficulties to be a sufficient barrier to the introduction of safer and more efficient working patterns offshore. In practice the changes will be minor for patterns already close to the optimum. The changes will impinge more heavily on those duty holders working patterns shown to be dangerous but who would not want to change-out a dangerous work pattern?

The HSE goals with respect to shiftwork

The overarching objective for the HSE with respect to shiftwork has to be the reduction to zero of the incidence of accidents in which the negative consequences of shiftwork or fatigue were wholly or partially causal. This can be extended to the more constructive objective of promoting mental and physical performance so as to maximise the error recognition and handling abilities of the workforce. The latter goal has the benefit of recognising the importance of the human operator's role as a critical part of the safety barrier system.

These high level goals have to be realised operationally through activities which are manageable and measurable. These are:

1. The recognition by managers, engineers and technical staff that shiftwork and work scheduling are manageable hazards.

Questions such as "who is responsible for determining the shift pattern" or "how do you know it is working well" are typically met with puzzlement by management. The ownership and monitoring of shift-working often appears to fall into a gap between operational management, human resources and medical health monitoring. All these are important but ultimately the optimisation of human performance through fatigue reduction should be a part of the operational management's' responsibilities. The HR function can facilitate and the medical dept can advise and monitor health. The engineers have to come to understand that the design of equipment determines its ease of use and that determines how long it can be operated safely. If too many similar incidents occur then something has to be changed. One engineer has assured me that an under-balanced drilling operation was "safe" because it required such high levels of attention over the 12-hour shift that no operator would make an error! That is akin to arguing that transatlantic flights would be safer if the pilot disengaged the auto-pilot and flew the plane manually. What nonsense! Human performance has very finite limits when fatigue sets in and errors rise. Furthermore as our task performance degrades so does our ability to monitor our own performance, we are not aware of the errors, it's a common mode failure as our output and monitoring systems are part of the same neuro-biological system.

The Human Factors Engineering approach pioneered by Gerry Miller[vi] in the US integrates HF practitioners into the engineering procurement cycle and addresses exactly these problems.

2. A unified approach to shiftwork in which work scheduling, manning levels and the nature of the activity form part of a single fatigue management system.

When we look at those situations where excessive hours have lead to a fatigue related incident we often find that not only was the working schedule excessive, but also low manning levels had removed back-up staff who could share the work load when fatigue set in. We also find that scheduling and manning levels often fail to take account of the nature of the task or the prevailing conditions. Tasks with continuous attention demands, i.e. watch keeping, or control panel monitoring are very difficult to sustain for 12 hours, as are physically demanding tasks like manual handling or drill floor work. On the "shop floor" the demands of the job, the length of the schedule and the level of support (or lack of it) come together, yet these are often dealt with in isolation when they are being determined.

3. The integration of shiftwork into the Safety Management System (SMS).

The UK legislation requires an effective Safety Management System SMS to be in place. We have found formal SMS methods to be very effective in maintaining effective management control of risks. However the risks posed by fatigue are not usually part of the risk control elements in the SMS, despite the major role that fatigue plays in incident causation. The SMS is the proper place for control and monitoring of fatigue induced performance decrements along with all the other identified hazards.

4. Management is responsible for the shift work over the whole duty or tour cycle.

The requirements of the offshore tour begin long before the arrival on the installation. Helicopter flights often have early morning departures and check-in times can be an hour before that. In the UK many offshore workers were recruited from the old steel, mining or ship building towns and consequently face road journeys of many hours to reach the heliport. It is difficult to obtain objective data but recent analyses of single vehicle road fatalities[vii] shows a prevalence in the early morning with drivers falling back to sleep within 30 minutes of a very early start. A recent pilot survey in the UK Southern Sector identified early drives to the heliport as known hazard. A Norwegian survey of sleep prior to offshore travel found very poor sleep on the night before departure, particularly in those anxious about helicopter travel[viii].

The largest single complaint from members of the workforce and their families is the problem of extreme tiredness for the first two or three days of the rest period. Wives in a recent HSE survey[ix] referred to "zombie partners". Advice on managing this fatigue, planning activities and travel appropriately and the provision of accommodation where appropriate should all be considered as part of an employers responsibility when extreme work schedules are a necessity.

5. Working patterns and schedules are determined using research and operationally derived data combined with risk assessment.

Most offshore shift patterns do not appear to be based on any of the current research findings on sleep quality, adjustment or fatigue reduction. The details of the science will be addressed in more detail below, however it is sufficient to note at this point that historically neither the advice from the science literature nor the in-company data available from accidents and incidents has been used as an input to work scheduling. There are a number of reasons why this is so, for example a) the science is hard to interpret in an offshore setting, b) onshore derived data does not apply offshore, and c) accident incident data is often of poor quality and focussed on the technical rather than human performance failures.

6. Working patterns and schedules are fit and appropriate for the tasks being undertaken and performance is monitored within a culture of continuous improvement.

Two important barriers to improving the offshore working schedules are a desire to have one pattern meet all needs, and secondly the considerable resistance to any changes which could affect pay or working conditions. It may be impossible on inappropriate to attempt to operate a single working pattern for all of the diverse tasks found offshore. Computer scheduling and pay systems should make it possible to operate a number of "fit for task" patterns for tasks with high physical or mental demands, particularly under tough conditions, for example on an FPSO in poor weather.

Shift patterns have been overly identified with remuneration systems. The changes suggested in this paper are unlikely to require significant alterations to total working hours or the 12-hour day. The alterations will be primarily about start and finish times; removal of mid tour “swing” or “roll-over” shifts and risks assessment for fatigue. The current position renders incremental change required by continuous improvement impossible without repeated and lengthy exercises in change management and negotiation. The work scheduling should be positioned in the other risk and performance management domains and subjected to the same performance monitoring and incremental change as improved understanding and knowledge becomes available.

Advances in the Understanding of Working on Extended Nights Offshore

The principal advance in understanding performance on extended night shifts offshore is the finding that the majority of workers adjust their circadian rhythms to be more or less night adjusted. This finding has come from three different programmes of research funded by the HSE and its significance cannot be overstated.

What does “adjustment” mean?

By adjusted we mean that a night worker’s circadian rhythms are now in phase with their working hours. These circadian rhythms determine a large number of physiological including reaction time, hunger, digestion, body temperature, the need for sleep an ability to sleep, and a number of mental performance indices including reaction time, decision making ability, memory performance and attention. To be unadjusted is to be suffering from what is commonly referred to as “jet lag”.

Why is adjustment so important?

Adjustment is important because an adjusted night worker will perform like a day worker. Ability to perform will peak in the working period as will attention and appetite; ability to sleep will correspond to the daytime off-duty periods. Poor sleep and indigestion are the two most widely reported problems in shift-workers. Many researchers believe that reduced sleep and digestive problems are a significant contributor to long term ill health in shift-workers.

Adjustment is important because it provides a guide in the design of offshore work schedules; they should promote adjustment while minimising the negative effects.

Why is this so important to the offshore oil industry?

The offshore oil industry is the only major industry in which workers have been found to adjust to permanent night work[x]. It is probable that a small minority of workers adjusts in other industries onshore but the effect will be much less marked. The offshore industry is also the only industry working continuous 12-hour nightshifts. Almost all of the current shiftwork advice is derived from onshore experience with unadjusted workers. Unadjusted workers perform poorly on extended night duty and do not have good day sleep. This situation has lead to the widespread adoption of fast rotation shifts onshore and pressures to reduce night work to a maximum of 5 hours duration. Neither of these is at all relevant to the offshore situation. Advice for unadjusted onshore workers will be intended to maintain them in their unadjusted state and so will focus on cueing in to day light, this is the exact reverse of the advice for adjusted night workers who should avoid all day cues.

What evidence do we have that offshore workers adjust their circadian rhythms?

The scientific evidence for adjustment to nights offshore comes from three independent research programmes funded by the HSE. These programmes span many years and contracts but there three key research teams are: Dr Kathy Parkes at the Department of Experimental Psychology, Oxford University; Professor Josephine Arendt at the Department of Biological Sciences, University of Surrey; and Dr Barbara Stone and Dr Michael Spencer of the Defence Evaluation Research Agency Centre for Human Sciences.

The work of Dr Kathy Parkes at Oxford

This work is published by HSE in a series of reports[xi]. The main body of the work addressed psychosocial aspects of work offshore and is published in five parts[xii]. The key findings in relation to shiftwork are:

Note: 14N = 14 continuous nights
14D = 14 continuous days
7N+7D = 7 nights followed by 7 days (a rollover)
7D+7N = 7 days followed by 7 nights (a rollover)

Sleep, mood, and workload

Rollover rotation patterns had adverse effects on sleep duration and quality, as compared with the corresponding fixed-shift conditions. The short off-duty periods associated with rollover schedules were reflected in significantly reduced sleep hours; for the 7N+7D rotation, impaired sleep continued almost to the end of the second week offshore.

Personnel working day shifts in the first week showed a relatively constant and favourable pattern of subjective alertness; among those working two weeks of day shifts, this stable pattern continued throughout the tour.

Adjustment to nights shifts, either at the start of the first week or following rollover, resulted in significantly decreased alertness from the start to end of individual shifts; however, the 14N group working two weeks of night shifts showed progressive adaptation, resulting in relatively stable alertness in the second week, comparable with that of the 14D group.

Rollover, irrespective of direction, had markedly adverse effects on subjective alertness during the first two shifts following the shift-change, persisting throughout the second week in the nights-to-days rollover group.

Positive mood in the 7N+7D group, relative to the 14N group, was adversely affected by the rollover for the remainder of the work cycle, but the adverse effects in the 7D+7N group occurred only during the first shift after the rollover.

In the 14D group, some evidence of a possible cyclic effect of positive mood was found; low mood occurred early in the second week but recovered before departure.

Perceived workload level decreased across the two-week tour in both the fixed-shift groups whereas, in 7D+7N group, significantly reduced workload over the rollover was compensated by higher subsequent levels.

Reaction time

Reaction time was relatively stable in the 14D group throughout the two-week work cycle, and in the 14N group, once initial adaptation had occurred.

Both rollover groups were adversely affected by the mid- cycle shift change, reaction time increasing sharply immediately following the rollover. In the 7D+7N group, mean RT increased by an average of 10.7% during the two shifts following the rollover as compared with the 14D fixed- shift group. The corresponding increase for the 7N+7D group was 5.2% as compared with the 14N group.

Increased reaction time from start to end of individual shifts was particularly marked at the start of night-shift sequences.

Within-person RT variability increased over the three phases irrespective of the shift rotation pattern being worked; this trend is consistent with cumulative fatigue effects over the two-week offshore work cycle.

Rollover groups showed significantly higher frequencies of gaps (reaction times greater than 1 second) than the fixed shift groups, particularly during the two shifts immediately following the rollover.

Direct comparison of RT profiles for the two rollover conditions confirmed that, when day shifts followed a week of night shifts, the normal level of day-shift performance is impaired.

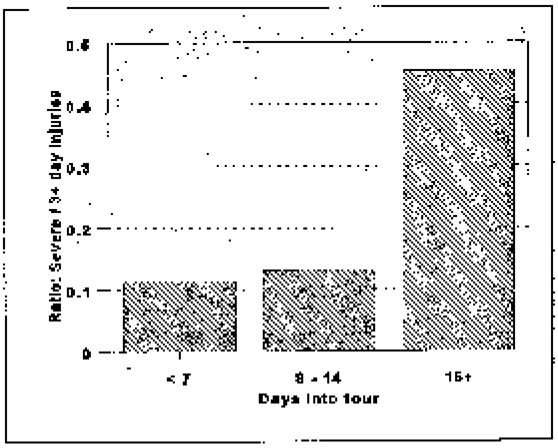
A further investigation was undertaken using the HSE database of statutorily reported incidents and the internal company accident records made available from the records of large multi-national oil and gas companies.

The data sets provided information about the nature and severity of injuries incurred by UK offshore personnel, together with details of temporal aspects of the accident (e.g. clock time, hours-into-shift, day-into-tour), the activity being carried out, and the body part injured. The HSE data included only three injury severity categories (fatality, serious injury, 3+ day injuries), whereas the company data included additional minor injury categories. Recoding of information was carried out where necessary to produce variables that, as far as possible corresponded across the three databases.

The data were analysed to identify trends in injuries in relation to temporal and occupational factors. In carrying out the analyses, it was necessary to take into account that the numbers of personnel exposed varied across times and in different jobs. As no exposure rate data were available, fatalities and serious injuries were analysed in relation to minor injuries, the latter being taken as a proxy measure of exposure rates.

All main findings from analysis of the HSE database (which were generally consistent with findings from the two company databases) were as follows:

Days-into-tour. For tour durations longer than two weeks, the ratios of fatalities and severe injuries to 3+ day injuries increased markedly, relative to durations of one and two weeks. The pattern was less evident among drillers but in this group the ratio was relatively high during both the first and



second weeks.

Day vs. nightshifts. The distribution of injury severity differed significantly across day and night shifts, night shifts showing higher rates of fatalities and serious injuries relative to less serious injuries. This effect was independent of days-into- tour.

Hours-into-shift. Injury severity was generally independent of hours-into-shift, although there was a significant effect when hours-into-shift was divided into two categories, 0- 12 hours and 12+ hours, a higher proportion of fatal/serious injuries occurring for the latter condition. This effect was particularly marked for drilling personnel.

Clock hours. For all two-hour time periods, except 23.00 - 0 1.00 hours, there were more 3+ day injuries than serious injuries; however, the pattern was reversed between 23.00 - 01.00 hours, this effect being due to the high rate of serious injuries occurring between 24.00 - 01.00 hours.

Injured body part. Injuries to the hand, shoulder or arm were most frequent; they accounted for the majority of crush injuries. Legs were the next most frequently injured body part, accounting for a relatively high proportion of strain/sprain injuries. However, these findings differed to some extent across day vs. night shifts, and across job types.

The work of Professor Jo Arendt at Surrey

Professor Jo Arendt and her team at Surrey University have been pioneers in the emerging science of chrono-biology. Their research had lead them to measure the hormone melatonin as a biological marker for adjustment in diverse groups with unusual light exposure, such as polar scientists, the congenitally blind, and latterly offshore oil workers. In these studies the rhythmic production of the hormone melatonin is assessed via its urinary metabolise 6-sulphatoxymelatonin, together with sleep and activity measures.

The early small-scale work offshore was funded by a major operator but it became clear that a larger centrally funded project with participation from a number of companies would be required. The first phase of that work is now underway and it is just possible to make some statements based on emerging data.

Results so far have confirmed that offshore workers do adjust[xiii] to consecutive nights at rates of approximately 1.5 hours per day when working an 18:00 - 06:00 duty. In all bar one subset the adjustment was by means of phase delay. Subjects included maintenance workers and drill floor crews and while it was hypothesised that the additional physical demands of the drill floor work would aid adjustment no such effect was found. Although this study is equivocal regarding the effect of exposure to natural light subsequent studies point very strongly to light as the major influence in entraining the melatonin and hence other circadian cycles. There were seasonal effects with a larger variance in the dates of adjustment in the summer than in the winter but these did not effect the direction of overall magnitude of the effects.

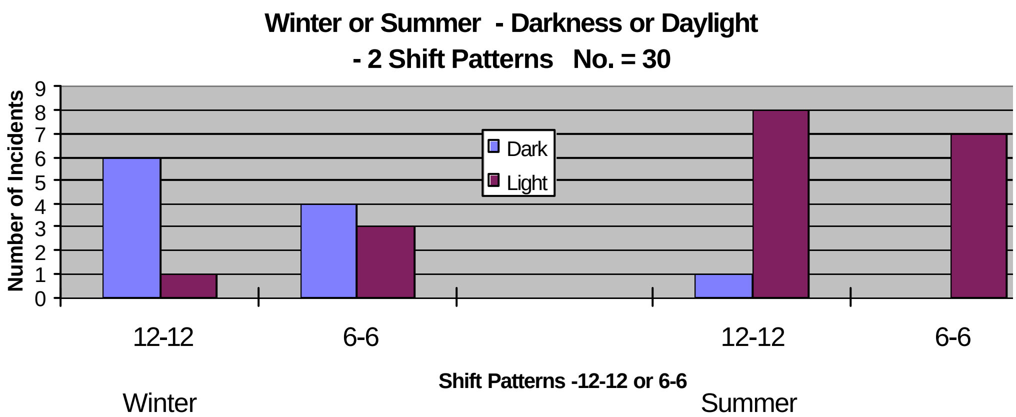
In a later study[xiv] of drill workers on a 00:00 – 12:00 / 12:00 – 24:00 pattern large seasonal effects were found. One crew studied in November showed no significant change in their 6-sulphatoxymelatonin rhythm during the night shift, another group studied in March showed adjustment by phase advance.

Quoting the researcher's most recent report[xv]:

> "This research indicated that on North Sea rigs, for a 14-day, 12-hour night shift, 1800-0600h, subjects are out of phase for at least the first 4-5 days of the night shift and for 4-5 days on returning home (Barnes et al 1998a). For a 7 day sequence, 12 hour shift, starting with night shift (1 800-0600h), subjects would be out of phase for at least 4-5 days out of 7 days on night shift followed by 4-5 days out of phase on day shift. Thus in the latter case optimal working conditions might only be achieved for 4-6 days of a 14 day period on the rigs. For a 7 day sequence starting with day shift (1200-2400h) then switching to night shift (2400-1200h) the majority of crew do not adapt to night shift (Barnes et al 1998b). These observations require further confirmation, and, if appropriate, strategies to counter the actual and potential health hazards should be investigated. Thus during an adaptation period workers are exposed to a number of unusual factors Potentially deleterious to health. "

Well kicks are reportable to the HSE as a dangerous occurrence. "Control times" vary from 50% within 24 hours, to 11% taking over 18 days to bring under control. Apart from the potential dangers, a kick can cost the Operators between $100,000 and $1.26 m a day in lost production time. Over the last 9 years the number of kicks taken annually in the UKCS has reduced by a very small amount. Most of the research has dealt with the technical issues of well control but the small decline in the number of kicks suggests that human factors are still playing a large part in kick initiation.

The results from this study have shown that between the two predominant shift patterns (i.e. 12:00 to 24:00, 24:00 to 12:00 or 06:00 to 18:00, 18:00 to 06:00,) there is no significant difference in the "Number of Incidents", the "Time of Year" and "Light or Dark".



As a result of these findings HSE commissioned a separate review of well control incidents to see if there was a related seasonal effect for the 00:00 – 12:00 / 12:00 – 24:00 pattern in comparison with the 06:00 – 18:00 / 18:00 – 06:00 pattern[xvi].

However there is a statistically significant difference in the number of incidents in both shifts in "Winter/Dark" and "Summer/Light" (P> 0.05). There is a significant difference in the "Time of

Day" (P> 0.05). There is a large increase in the number of kicks around midday for both shifts but a stronger significance for the 6-6 shift. There is also a statistical significance in the number of incidents surrounding crew change (P> 0.05). Although the numbers for this part of the analysis were low (16 incidents), 50% of these incidents occurred the day before or the day after crew change. There is an increase in incidents around midnight in the winter for the 12-12 shift. More kicks are taken by the 12-12 shift in darkness and between 18:00 and 06:00 hours than the 6-6 shift.

Most noticeably there are no reported summer kicks in the dark for the 6-6 shift workers (see fig) out of 30 incidents.

It was impossible to correct the absolute numbers of incidents for rate of activity as this was not recorded, but the key result is that the distribution of kicks is subject to shift and seasonal effects to a significant degree. This strongly supports the importance researching and managing adjustment. What is not yet clear is which of these two patterns is best. For a number of reasons which will be described later in this paper, HSE, and a number of researchers, are coming to favour the 06:00 to 18:00 / 18:00 to 06:00 pattern.

Because the Surrey research indicated that adjustment duration could span 4 to 5 days part of the remit of the new larger programme with the Surrey researchers was to investigate mechanisms which could shorten adjustment phase, both when coming on to nights offshore, and again when adjusting back to days on leave. That work has only just begun but measurements are being taken of sleep duration and quality and detailed diaries of diet and activity together with work place light levels. There is evidence[xvii] that diet may be able to aid in promoting adjustment or mitigating some of the negative consequences during the adjustment phase and that moderate increases in lighting level at specific times may also be effective. Management of light levels with bright work areas and effective daytime black-out for night workers is imperative if adjustment is to be effective. A recent HSE study[xviii] of a new build FPSO found the all of the cabin windows, fitted at great expense with to a 1 hour fire rating, had been taped over with black plastic rubbish bags so that the night workers could sleep. Clearly the design engineers were totally unaware of the concept of adjustment and how to promote it; the workers did know and arrived at a local solution.

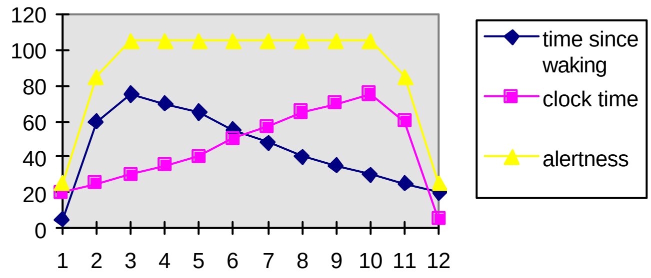
The work at the Defence Evaluation Research Agency (DERA) Centre for Human Sciences

The HSE commissioned DERA to develop a fatigue risk assessment index based on DERA's previous work with the military. The index was specifically for use onshore in unadjusted working populations.

The model developed by DERA has two components of alertness/performance; a) time since waking, and b) time of day. In a normal day worker the time since waking curve peaks early in the working day then drops steadily through the day. The time of day component rises throughout the day and peaks late afternoon. These two components add to give an indication of overall alertness. The two components correspond to neuro-physiological mechanisms evolved to maintain alertness throughout the daylight waking period. In an unadjusted night worker the time since waking component is 12 hours out of phase and so both components peak early and then fall very rapidly.

This is corroborated by performance studies on night workers who show high performance early in the night shift, often above that of day workers. Unfortunately by the end of the shift alertness and performance are well below that of a day worker. In an adjusted night worker the time of day component has shifted by 12 hours to provide the necessary boost later in the working period. In practice the phase shift is likely to be between 6 and 8 hours and alertness and performance will come close but no quite equal day performance. This partial adaptation occurs because there are always confounding environmental cues (i.e. stray daylight, TV, etc) which hold back the adjustment.

The DERA model: Day worker:



The DERA model: unadjusted night worker. Note the adjusted night worker would look like the day worker but 12 hours phase shifted. (schematic only)

Field trials of the DERA index on a number of work groups found only one group who's performance on night shifts improved over the two week study period. All other groups in a variety of onshore industrial sectors showed marked declines in alertness over a night shift. The group who improved was a standby vessel crew working 14 consecutive 12-hour nights.

Some other important lessons from recent research

Dr Lawrence Smith and Dr Peter Gardner of the Shiftwork and Safety Research Group at Leeds[xix] have investigated the effect of bright light on night shift control room workers in the nuclear industry. The shift pattern was fast rotation so the workers would not welcome excessive adjustment. However while the increased night time alertness was not popular, performance, mood and daytime sleep all improved. Had the shift pattern been permanent nights this intervention could be expected to be both effective, and popular.

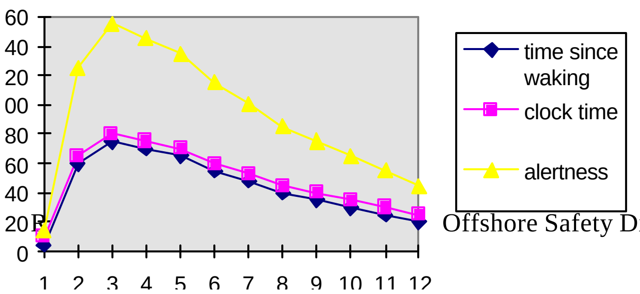
Although early work with so called “day light” lighting had required very high light levels the work at Leeds found that more modest increases in the 300 - 500 lux range were effective in promoting adjustment if timing and duration are carefully controlled.

The work at Surrey has also increased our knowledge of the importance of the melatonin cycle in determining sleep onset and ability to sleep. While increases in melatonin initiate sleep the converse is also true, it is very hard to commence sleep when levels are low. This is the so-called “forbidden sleep” period and in day subjects would be a few hours before normal sleep onset. The consequence of this effect is that it is all but impossible to force sleep early when faced with an earlier start the following day. Early starts always occur at the expense of sleep and the evidence from road accidents is that they pose a major risk factor.

Discussion

The evidence from the research reported above suggests that that offshore oil workers adjust their physiology and hence cognitive performance to night work and in this they unlike almost all other employed groups. The performance and alertness data favour a continuous period of nights with maximal adjustment. The incident data suggest that other constraints, probably cumulative sleep loss, limit this duration of consecutive nights to 14. If extended consecutive nights beyond 14 were intended i.e. 21 or 28, then day sleep quality would have to be as good as normal home night sleep so that no cumulative loss occurred. One threat to sleep is overtime as it allows very little time for rest, washing, sleep and meals. The Oxford researchers found 20% of day workers and 8% of night workers reporting 100+ total hours per week. Sleep is also the recovery period from the physical (noise, vibration etc) and chemical exposures of the work period.

A complication factor is that currently the shift pattern most popular with the workforce is the 7N + 7D. This has the major advantage for the worker of placing all of both the adjustment phases during the offshore period. Return to home is in a fully day adjusted state. Conversely the 14N (alternating 14 D on the next tour) places one adjustment offshore and one onshore. It also halves the total number of adjustments, as there are only adjustments on alternate tours offshore. A number of researchers now believe that the number of adjustments is one of contributory factors to long term health problems in shift workers and therefore schedules with less adjustments should be better in the long term. It



may be assumed that non-adjusting fast rotation schedules are better in this respect however that may not be the case as rather than the acute adjustment followed by a period of stability as with the 14 nights, the fast rotation produces a prolonged period of partial adjustment which may be equally bad for health..

The 14 N schedule can be very unpopular with spouses (the "zombie partner" syndrome) and may increase travel risks on reaching the beach. One operator who recently changed from a 7N + 7D pattern to 14 N found staff complaining about being useless for three days on return to the beach. Our data suggest that compared to 14 nights they would reach approximately 90% of the adjustment after the first seven nights offshore after 7 nights on the old pattern and would have experienced very similar losses of performance while offshore during the second week. The analyses of the rise in incidents around the rollover period support this. Interestingly this issue of poor performance after 7 or more nights had never been raised until it impinged on home life.

This places both the HSE and the Duty-holder's management in a difficult position. The more the objectors to a 14 nights shift pattern talk up the problems of fatigue when returning to days the harder it is for either HSE or management to condone a change back to 7N - 7D. Agreeing to such a change would recognise that fatigue at work posed a safety risk, as the effect of changing to days after 7 nights is very similar to that after 14 nights.

We have been investigating this adjustment back to days offshore after 7 nights and results so far suggest a complex and confused picture with some individuals achieving this adjustment by moving their circadian rhythms forward and others backwards. Either way these preliminary findings do not support the proposition that adjustment back to days is easier in the regimented regime offshore.

The 00:00 – 12:00 / 12:00 – 24:00 pattern found on some drilling rigs is difficult to assess. It seems likely on current evidence that this is a particularly poor schedule as neither "night" nor "day" shift is adjusted and there is also a rollover. The marked seasonal effect found with this pattern supports this view. At least with the 14N schedule the 50% of staff on the 14D tour are performing fully, with the 14N shift performing less well for the first 3-5 days. On the 00:00 – 12:00 / 12:00 – 24:00 pattern it is probable that neither shift is performing to the best of their ability.

The adjustment back to days at the end of the 14 nights is the crux of the problem as it will take place during leave time. My own experience of facilitating workshops on this topic with members of the offshore workforce and safety reps is that, once the risks posed by the old system are explained and supported with the research findings, objections are much reduced. However the need for safe travel home remains and so does the need for spouses and other family members to understand the significance of the adjustment period and the best means to facilitate it. Road travel after a long tour always has posed a risk even without adjustment and any actions to reduce this should be welcome. With the 14 N pattern the extreme effects will only occur once every six weeks on a 14 on 14 off pattern.

Another challenge is that changing to a shift pattern that improves the performance of the workers by implication benefits the employer more than the worker. It is not yet possible to quantify the financial benefits of an optimal shift pattern but some equitable division of these between employer and worker would seem a sensible strategy. Dr Kathy Parkes found involvement in the choice of shift pattern and tour length exerted a major influence on subsequent satisfaction with the pattern[xx].

On the basis of the current state of knowledge the best advice would appear to be to adopt a strategy of adjustment with 14 consecutive nights followed by continued management of the adjustment back to days. Tours would alternate nights and days. Start times should not be before 6 am and unplanned call outs, overtime and sleep disturbance should be minimised so as to reduce cumulative fatigue effects. Incident and performance data need to be monitored in greater detail than at present if the industry is to align towards the most effective safe shift pattern(s). Involvement of the workforce in this monitoring would seem sensible as it improve understanding and buy-in while also putting any subsequent changes in the context of continuous improvement.

Evidence from workshops with members of the workforce and OIMs suggests that newcomers to the industry do not exhibit the same strong preferences for the 7N - 7D pattern over the 14N / 14D. OIMs of installations with newcomers who were recruited on to the 14N / 14D schedule report that these people prefer this pattern. A similar situation seems to occur with the 12/12 schedule common on mobile drilling rigs is that very few of those working it have experience of any other pattern, particularly the 14N / 14D as this is usually only found on production platforms.

None the less we will have to recognise that many offshore workers may chose to continue to work the less than ideal 7N - 7D schedule in the knowledge that it falls short of best practice and results in an increased risk due to fatigue. Under these circumstances a case could be made that the working arrangements do not meet the ALARP (as low as reasonably practical) test. However pragmatism may be the best course of action so that HSE would expect those duty-holders operating a 7N - 7D schedule to management every other aspect of their fatigue, working hours and staffing levels to an exemplary standard.

Lastly and not least, the health benefits of the 14 N schedule need to be quantified as these could prove decisive over the long term and could therefore also form an incentive for workforce and management to adopt this pattern.

Endnotes

[i] Prof. Jim Horne, Sleep Research Unit, Loughborough University; 1999 Institute of Petroleum Seminar on Fatigue, London

[ii] NASA Centre for Human Factors web site.

[iii] Reason. J: Human Error,

[iv] Parkes K R and Swash S. Injuries in offshore oil and gas installations; an analysis of temporal and occupational factors. 2000. HSE OTO report, in press.

[v] see “iv” above

[vi] OTC Houston 1999 Human Factors Session

[vii] see “I” above

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[xvi] Shift Patterns/Time of Day/Year and Drill Floor Accidents: HSE Research report, in press: Contract No. D3837: 2000

[xvii] as 14 above.

[xviii] Project 3669 Ergonomic considerations in the design of FPSO’s HSE OTO report in press 2000

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