A “SYSTEMS” APPROACH FOR MANAGING FATIGUE IN MINING OPERATIONS

Presented by:
Circadian Technologies
Stoneham, MA

www.circadian.com
Circadian Technologies, Inc.

- International research and consulting firm for 24-hour operations
- Based in Stoneham, Massachusetts (North of Boston)
- Outgrowth of Harvard Medical School and the discovery of human biological clocks
- Utilizes objective, scientific approach to scheduling and shiftwork issues
- Assist companies improve operating efficiency and overall health, safety & employee work/life balance through development of Fatigue Risk Management Programs (FRMP)
CTI has been privileged to work in all types of round-the-clock businesses world-wide, where scheduling and shiftwork problems significantly impact productivity, quality, safety, and quality of life, including:

- Mining
- Oil/Chemicals
- Utilities
- Pulp & Paper
- Manufacturing
- Food & Beverage
- Call Centres
- Hospitals
- Police/Fire
- Pharmaceuticals
- Primary Metals
- Railroads
- Aviation
- Marine
- Trucking/Bus
- Mass Transit
- Insurance
- Government
- Banking
- Biopharmaceuticals
Some of CIRCADIAN’s ® Clients
FATIGUE RISK MANAGEMENT: The Challenge

Global economy and modern equipment efficiently runs 24/7

But human design specs are not
INHERENT FATIGUE RISK MANAGEMENT CHALLENGE IN MINING OPERATIONS

MODERN EQUIPMENT AND TECHNOLOGY RUNS EFFICIENTLY 24/7...

WE HUMANS DO NOT...
Design Specs of the Human Body

Humans were not designed for peak performance at night.
The body has many circadian rhythms. This chart shows a few of the many bodily functions which exhibit a normal daily rhythm, including (1) core body temperature, (2 & 3) secretion of hormones such as growth hormones and stress hormones like cortisol, and (4) levels of electrolytes such as potassium in the blood and urine.
Alertness Variability Over 24-Hour Period

- Full Alertness
- Moderate Alertness
- Reduced Alertness
- Drowsy

Source: Circadian Technologies, Inc. (1993)
LAWS OF CIRCADIAN SLEEP PHYSIOLOGY
Circadian Rhythms in Human Performance

WOCL = Window of Circadian Low

Source: Moore-Ede 1993

Time of Day
DETERMINANTS OF HUMAN ALERTNESS: Extended Hours Without Sleep

Source: Circadian Technologies, Inc. (1993)
APPLYING FATIGUE MANAGEMENT STANDARDS TO IMPROVE OCCUPATIONAL HEALTH AND SAFETY

A cooperative (win-win) effort between management and labor to reduce shiftworker fatigue and its costs for the company and its employees.
FATIGUE RISK MANAGEMENT "SYSTEMS" (FRMS) IS A HOLISTIC APPROACH THAT ADDRESSES MULTIPLE SOURCES OF FATIGUE

Corporate Culture and Management Attitudes

- Staff/Workload Balance
- Training & Education
- Workplace Environment
- Sleep Disorders

Human Fatigue Risk

- Work Schedule Design / HoS Standards
- Work/Rest Standards
- Employee Behavior
- Compliance Monitoring and Human Error Analysis

Policies and Procedures
JAMES REASON’S
Multiple Causation Theory

Lining up risks

Driver awareness

Safe road conditions

Safe vehicle

Safe traffic conditions

High-volume traffic

Low tire tread

Raining

Hands-free phone conversation

Accident

Successive layers of defences, barriers, & safeguards

Source: Reason 1990
INTEGRATED FRMS MODEL

**SLEEP**

**Defense 1**
- Sufficient Staffing Levels

**Defense 2**
- Sufficient Sleep Opportunity

**Defense 3**
- Employee training
- Sleep disorder treatment & compliance

**Defense 4**
- Sufficient Workplace Environment

**Defense 5**
- Sufficient Alertness Behavior

**Tasks & Accidents**

**Alertness**

**Defense 1**
- Sufficient Staffing Levels

**Defense 2**
- Sufficient Sleep Opportunity

**Defense 3**
- Employee training
- Sleep disorder treatment & compliance

**Defense 4**
- Sufficient Workplace Environment

**Defense 5**
- Sufficient Alertness Behavior

**Fatigue Risk Root Cause Analysis and Continuous Improvement**
Premise: Fatigue can be generated by excessive work hours & lack of rest due to inadequate staffing levels

Provide an adequate staffing level to:

- Maintain overtime at or below 10% of an average 40-42 hour work week
- Consistently work within recognized Hours of Service Guidelines
  - Consecutive & total workdays
  - Time off between consecutive shifts and worksets
- Account for and provide coverage for anticipated levels of training, vacations, sickness and other absences
Premise: Excessive fatigue can be generated by excessive work hours or lack of rest caused by the core schedule.

Design Biocompatible Shift Schedules focused On Three Main Criteria:

- Operational Requirements
- Employee Preferences
- Physiological Requirements

Goals
- Sufficient Sleep Opportunity
- Shift / Duty scheduling, Overtime policies, Fatigue risk models
- Schedule Driven Fatigue Risk

Actions
FRMS Defenses in Depth
#2. Core Schedule Design:

**Biocompatible Schedules**

- Max Shift Length
  - Routinely: \( \leq 12 \text{ hrs} \)

- Consecutive Workdays
  - 7 with 8-hour shifts
  - 4-5 with 12-hour shifts

- No Start Time Between Midnight - 5:59 a.m.

- Time Off Between Work Blocks -- No Less than 48 Hours

- Slow Rotation (easier on body)
#2. Schedule Design: Outer Limits

<table>
<thead>
<tr>
<th>Operational Situation</th>
<th>12-Hour Shift</th>
<th>10-Hour Shift</th>
<th>8-Hour Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Consecutive Shifts (Day or Night)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In a Work set</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Normal Operations</td>
<td>7 shifts</td>
<td>9 shifts</td>
<td>10 shifts</td>
</tr>
<tr>
<td>b) Outages</td>
<td>14 shifts</td>
<td>14 shifts</td>
<td>19 shifts</td>
</tr>
<tr>
<td>Minimum time off after a work set</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Normal Operations</td>
<td>36 hours</td>
<td>36 hours</td>
<td>36 hours</td>
</tr>
<tr>
<td>• Work set of 4 or more night shifts</td>
<td>48 hours</td>
<td>48 hours</td>
<td>48 hours</td>
</tr>
<tr>
<td>• After 84 hours or more regardless of day or night</td>
<td>48 hours</td>
<td>48 hours</td>
<td>48 hours</td>
</tr>
<tr>
<td>b) Outages</td>
<td>36 hours</td>
<td>36 hours</td>
<td>36 hours</td>
</tr>
<tr>
<td>Extended Shifts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Unscheduled maximum shift</td>
<td>18 hours</td>
<td>16 hours</td>
<td>16 hours</td>
</tr>
<tr>
<td>b) Time off after shift</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 10 to 16 hour shift</td>
<td>N/A</td>
<td>N/A</td>
<td>8 hours</td>
</tr>
<tr>
<td>• 12 to 16 hour shift</td>
<td>N/A</td>
<td>8 hours</td>
<td>N/A</td>
</tr>
<tr>
<td>• 14 to 16 hour shift</td>
<td>8 hours</td>
<td>8 hours</td>
<td>N/A</td>
</tr>
<tr>
<td>• &gt;16 to 18 hour shift</td>
<td>10 hours</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Maximum Number of Extended Shifts per Work set</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

1 for 14 hour shift or 2 for 12 hour shifts or for 3 or more 12 hour shifts, follow 12 hour normal operations guidelines above. 2 if greater than 12 hours in duration; extended shifts must be non-consecutive. If >2, follow 12 hour normal operations above.
Premise: Fatigue can be minimized by providing employees and managers with training on how to improve sleep and minimize unique stress factors that come with shift work.

- Basic sleep, circadian, and fatigue physiology
- Strategies for achieving good quality, restorative sleep including sleeping quarters design
- Recognizing symptoms of sleep disorders
- Managing an alert and healthy lifestyle
- Understanding risks of fatigue impairment
- Recognizing the signs of fatigue impairment and ways to mitigate them
Most of the digestive problems for shiftworkers can be summed up in one phrase:

“Eating the Wrong Food at the Wrong Time”
Your Biological Clock and Your Stomach

Typical Daytime Schedule

Time of Day

Your stomach anticipates meal times in the day
At night, your stomach does not expect to digest food.
Caffeine…The Pro’s:

- Can increase alertness
- Can improve reaction time
- Can improve performance
- Can improve overall energy
- Works quickly (in about 30 minutes)
- The effects last for 3-5 hours in most people
The Cons:

• Can cause gastrointestinal problems
• Stays in the body for several hours
• Caffeine is addictive; a dependence can develop
• May worsen some sleep disorders
• High levels promote stress, anxiety and irritation
• Coffee is a mild diuretic (increases urine production)
• Cutting back can cause withdrawal symptoms
FRMS DEFENSES IN DEPTH
#3: SHIFTWORK LIFESTYLE TRAINING

Relationship between caffeine use (cups/day) and frequency of gastrointestinal problems. Source: Circadian employee database.
Energy Drinks

- **Becoming ever more popular**
- **U.S. sales were $10 billion+ in 2012**
  - Especially among younger shiftworkers (prefer over coffee)

- **Where does “energy” come from?**
  - Caffeine
  - Sugar
  - Vitamins (e.g. B12, B6, B3)
  - Amino Acids (e.g. Taurine, L-Carnitine)
  - Herbs and other natural (e.g., Ginseng, Guarana)

- **Classified as “Dietary Supplements” by FDA**
  - Energy claims do not have to be proven scientifically
  - Do not need to disclose amount of each ingredient
  - Soda classified as a “functional food” – must list precise ingredients
5-Hour Energy

- 4 calories
- caffeine based
- sugar free
- contains B vitamins and amino acids
- fruit flavored
- called a "dietary supplement"
- touted as a "pick me up" to increase alertness and energy
- company claims it "significantly" outperforms placebos in attention and alertness tests
- company tests haven't been published or peer reviewed to screen biases
- independent tests show that it contains about 207 mg of caffeine, compared to an 8 ounce serving of Starbucks coffee, which has 180 mg
- no research to suggest that B vitamins or amino acids provide any boost
FRMS DEFENSES IN DEPTH
#4: Sufficient Workplace Environment

Premise:
Fatigue can be significantly impacted by work environment

Six of the nine switches of alertness are influenced by job design and workplace environment.

Goals
Actions
Metrics

Sufficient Workplace Environment
Job stimulation Workplace design, Light color filtering,
Workplace Environment Fatigue
Premise: Even when staffing levels, schedules, training and work environmental have been optimized, fatigue can still be present and means to detect fatigue and intervene prior to incident are necessary.

Policies and Procedures
Technologies
Technology

- Camera based, non-contact, non-intrusive sensor observing the driver
- Measures eyelid closure
- Measures head orientation

Event Types Detected

- Fatigue events characterised by extended eye closure duration > 1.5 sec / speed > 4 mph
- Distraction events characterised by glances away from the road duration > 4.5 sec / speed > 10 mph

*Technology alone is not the “silver bullet”*
Investigations of incidents should be conducted in a manner that facilitates the determination of the role of fatigue as a root or contributing cause.

Information collected should include:
- Time of the incident
- Shift pattern, including the number of consecutive shifts worked
- The number of hours awake
- The number of hours of sleep in the past 24-72 hours by the individuals involved
- Shift duration and any overtime worked
- Operational condition: normal operation, extended shift, call out, outage

Since it is common that no definitive conclusion can be reached on the role of fatigue in an individual incident investigation, a periodic aggregate analysis of incidents should be conducted to look for patterns suggestive of fatigue.
FRMS Defenses in Depth
# 6 Fatigue: Root Cause Analysis

Fatigue Accident / Incident Causation Testing System (FACTS)

Your Incident/Accident ID (optional)

Facility / Region ID

Timing of the Incident

What was the Date of the incident? 02/13/2011

What time of the day did the incident occur? 4 AM

How many hours prior to the time of the incident, did his/her last sleep episode end? 6

At the time of the incident, what kind of activity was the individual performing? Operating a Vehicle (as part of job)

At the time of the incident, how many hours had the individual been on duty? 3

Sleep during the nights / days prior to the incident

The following set of questions helps to collect information about how much and how well the individual slept in the last 3 days/nights:

- How many hours of sleep did the individual get in the 24 hours prior to the incident? (Include main sleep and naps) 2

FACTS CASE RESULTS

Fatigue Accident / Incident Causation Testing System (FACTS)

FACTS CASE RESULTS

Based on the information provided, FACTS determine the following result:

- Fatigue Level
- Probability
- Risk

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EXCESS COSTS OF FATIGUE IN SHIFTWORK OPERATIONS

Total excess cost of increased absenteeism, turnover, health care, incidents & accidents and productivity loss averages $10,100 per shiftworker per year.

- Absenteeism: 25%  
- Turnover: 19%  
- Accidents: $8.5 Billion  
- Healthcare Costs: 14%  
- Productivity: 38%

Source: Kerin & Carbone 2003, CPI adjusted 2010

TOTAL COST/YEAR US ECONOMY = $242.5 BILLION
Safety Costs: Haulage Truck Accidents

- 77% of serious injuries occurred at strip or open pit mines (3 times higher than other mining operations)

- Driving over the edge resulted in 37% of serious injuries and 85% of fatalities.

- 93% of surface mine haulage truck accidents due to human error

- 60-70% of human error accidents are fatigue-related

CONCLUSION:

- Fatigue is inherent in all shiftwork operations
- Fatigue directly correlates with human error and accidents
- Costs, risks and liabilities of fatigue are substantial (minimum $10,100 per 24/7 employee, excluding collateral costs, productivity loss, and litigation costs)
- New analytics provide ability to quantify costs of fatigue, justify FRMS, and monitor/control ROI results
- New standards provide guidelines / roadmaps for FRMS development
- FRMS DOES PROVIDE A PATHWAY TO THE NEXT STEP CHANGE IN HSEQ AND HUMAN PERFORMANCE