

White Paper  
**Investigating the Possible Contribution of Fatigue to Pipeline Mishaps<sup>1</sup>**

James C. Miller, Ph.D., CPE  
June 2011

## **OBJECTIVE**

To determine whether there is a reasonable probability that fatigue was a probable cause or contributing factor in a mishap.<sup>2</sup>

## **WHEN TO USE**

Use these methods to investigate if fatigue may have contributed to the mishap. Especially, use these methods if the operators<sup>3</sup> of interest were shiftworkers, as defined by the U.S. Office of Technology Assessment (Office of Technology Assessment, 2005) and the National Institute for Occupational Safety and Health (NIOSH; (Rosa & Colligan, 1997). That is, they worked:

- Any evening or night work;
- A rotating shift, in which hours changed regularly (e.g., from day to evening to night);
- A split shift, in which a period of work was followed by a break and then a return to work;
- Extended duty hours consisting of long periods of work, usually over 12 hours;
- Outside the normal daylight hours (about 6:00 a.m. to 7:00 p.m.); or
- A “permanent” night or evening shift.

## **INITIAL SCREENING QUESTIONS**

If any of the following is true, then proceed with the methodology, below.

- Does the operator’s 72-hour history suggest little sleep or less sleep than usual?
- Did the mishap occur during periods of reduced alertness, i.e, about 2:00 to 6:00 a.m. or about 1:00 to 3:00 p.m.?
- Had the operator been awake for a long time at the time of the mishap?
- Does the evidence suggest that the mishap was a result of inaction or inattention on the part of the operator?

\* \* \*

## **METHODS**

It is important to establish two factors before concluding that operator fatigue contributed to a mishap. First, determine whether the operator was susceptible to fatigue effects because of insufficient sleep lengths, sleep disturbances, circadian factors, too much time awake immediately before the mishap, and/or medical issues.

Second, if the operator was susceptible to fatigue effects, then determine whether the operator’s performance and/or behaviors at the time of the mishap were consistent with the effects of fatigue.

---

1 Portions adapted from the NTSB’s Methodology for Investigating Operator Fatigue in a Transportation Accident, version 2.0, 2 June 2006

2 “Mishap” is used here to indicate an accident, an incident or a near-miss.

3 “Operators” includes shift leads, controllers, analysts, and others associated with the mishap.

### Susceptibility to Fatigue Effects

Determine whether the operator was experiencing sleep debt by documenting sleep/wake patterns for at least 72 hours before the mishap, and by learning about the operator’s typical sleep habits. Ask the operator. Interview family members or other witnesses. Use receipts, cell phone records, work schedules, log books, alarm clock setting, or other records.

- Determine the operator's typical sleep patterns: bedtimes and awakening times for work days and days off.
- Determine the operator's sleep pattern for at least 72 hours immediately preceding the mishap.
- Determine whether naps were taken in the days preceding the mishap. When, where, for how long, and why?
- If possible, determine the sleep quality for all sleep periods and naps.
- **Criterion 1:** Acquisition of less than about 21 hours of good quality sleep in the preceding 72 hours suggests that fatigue was present at the time of the mishap.
- **Criterion 2:** Acquisition of less than about 6 hours of good quality sleep in the preceding 24 hours suggests that fatigue was present at the time of the mishap.
- **Sleep Worksheet**
  - Fill in the Sleep Worksheet (below). If sleep times cannot be determined, then use the worksheet as a work start and end worksheet, and label it clearly as such.
  - The worksheet may be used at a later date for fatigue modeling.
  - Use one worksheet for each operator of interest.

Location (sleep at home, on-duty nap, nap at home, etc.)	Date and time of sleep start (e.g., 4/15/11, 10:30 p.m.)	Date and time of sleep end	Number of hours slept (e.g., 6.3)	Sleep Quality (Good/Poor)
<i>Suggestion: begin with the time of the mishap and work backwards.</i>				

Determine how long the operator had been awake at the time of the mishap. This is the length of time since the last major sleep period of at least six hours.

- **Criterion 3:** *More than 16 hours of continuous wakefulness suggests that fatigue was present at the time of the mishap.*

Determine whether the human fatigue factors problems associated with the mishap occurred during periods of reduced alertness.

- **Criterion 4:** *Occurrence during the periods of about 2:00 to 6:00 a.m. or about 1:00 to 3:00 p.m. suggests that fatigue was present at the time of the mishap.<sup>4</sup>*

Determine whether the operator suffered from circadian rhythm issues due to recent crossings of multiple time zones.

- **Criterion 5:** *Crossing three or more time zones within the same number of days preceding the mishap suggests that malaise was present at the time of the mishap.*

Determine whether the operator rotated to or from a night shift preceding the mishap

- **Criterion 6:** *Rotation to or from a night shift within the three days preceding the mishap suggests that malaise was present at the time of the mishap.*

Determine whether the operator suffered from sleep disorders or other sleep-disturbing medical factors. Sources include the operator's medical and pharmacy records. If applicable, have the operator evaluated by a physician who specializes in sleep medicine. Review the operator's toxicological results for substances that may affect sleep or alertness.

- Diagnosed with insomnia, narcolepsy, sleep apnea, and/or Shift Work Sleep Disorder (SWSD<sup>5</sup>)?
- Prescription medications for sleep- or sleepiness-related problems?
- Other medical concerns that affect sleep (e.g., chronic pain, Gastro esophageal reflux disease (GERD), etc.)?
- Other drowsiness-inducing medications?
- **Criterion 7:** *The presence of sleep disorders or other sleep-disturbing medical factors suggests that fatigue was present at the time of the mishap.*

Check for other evidence of fatigue:

- Check work records and records of previous mishaps/incidents (including DMV and/or insurance records) for evidence of prior falling asleep during vehicle operation.
- Determine what kind of training the operator received regarding fatigue management.
- Review the operator's mishap environment and tasks for unusual conditions that would depress arousability, such as low lighting, operational delays, or boredom.
- Determine whether there have been complaints of operator fatigue in the recent past.

---

<sup>4</sup> More information about the secondary, afternoon peak in accidents is available in the paper by J.C. Miller and M.M. Mitler (1997), Predicting accident times. *Ergonomics in Design: The Quarterly of Human Factors Applications*, 5(4), 13-18.

<sup>5</sup> Insomnia and excessive sleepiness associated with working and sleeping at non-standard times. *International Classification of Sleep Disorders (ICSD)*, American Academy of Sleep Medicine (AASM; [www.aasmnet.org](http://www.aasmnet.org)); Code 307.45-1, a circadian sleep disorder.

## Performance and Behaviors

Determine whether the operator's performance at the time of the mishap was consistent with the effects of fatigue.

- Overlooking or skipping tasks or parts of tasks?
- Focusing on one task to the exclusion of more important information?
- Delayed responses to stimuli or unresponsiveness?
- Impaired decision-making?
- Slow to adapt behavior to accommodate new information?
- Reduced frequency of communications?

Were the operator's behaviors before the mishap suggestive of sleepiness/fatigue, according to witness interviews, operator report of being tired, audio or video records of the operator's behavior, etc?

**Criterion 8:** *Performance and/or behaviors consistent with fatigue effects suggest that fatigue was present at the time of the mishap.*

## Conclusions

- A finding that the operator was susceptible to fatigue effects (meeting one or more of criteria 1 through 7) and demonstrated performance or behaviors consistent with fatigue (met criterion 8) indicates a reasonable probability that fatigue was a probable cause or contributing factor in a mishap.
- A finding that the operator was susceptible to fatigue effects (meeting one or more of criteria 1 through 7) without demonstrated performance or behaviors consistent with fatigue (criterion 8) should not be used to support operator fatigue as a probable cause or contributing factor in the mishap. However, the finding may still be an important safety issue to be addressed in the mishap report.