

# Executive Summary- Canalert Study

## Introduction

In response to a directive from Transport Canada to develop a plan to reduce the risks of train crew fatigue, Canadian Pacific Rail, Canadian National Rail, and VIA Rail Canada, along with the Brotherhood of Locomotive Engineers, established a joint labour-management Steering Committee. With the assistance of Circadian Technologies, Inc., the Steering Committee developed, implemented and tested a comprehensive Alertness Assurance Process, entitled CANALERT '95, the results of which are presented in this report.

Through a close collaborative partnership between employees, unions, and railway management, the root causes of locomotive engineer fatigue were identified and a set of specific fatigue countermeasures was developed for freight operations. These included circadian time pools, which established a more regular and predictable work-rest pattern, recuperative napping practices both off duty, and while trains were held in sidings, improved bunkhouse sleeping accommodations, headsets with music and intercom, and a railway lifestyle training program. Several of these countermeasures are also applicable to passenger operations, where studies were also conducted of the alertness and workload/stress of locomotive engineers and a comprehensive analysis was undertaken of their work schedules across Canada.

Based on the experience gained in the implementation of the fatigue countermeasures in pilot studies using an Alertness Assurance Process and the results obtained from a detailed analysis of alertness, sleep, and mental workload characteristics before and after fatigue countermeasure implementation, a series of recommendations is presented for assuring optimal levels of locomotive engineer alertness in the Canadian Railway system through a system-wide implementation of the Alertness Assurance Process.

## Fatigue in Railway Operations

The railway industry is highly susceptible to the risk of accidents and errors caused by human fatigue and loss of alertness. This susceptibility can be traced to several operational factors which distinguish the working conditions of railway train crews from those of other occupations. In particular, the railway industry requires round-the-clock service resulting in irregular hours of work. Duty periods are long, and there is often little advance notice prior to beginning a work assignment during which crews must maintain vigilance for sustained periods.

These factors combine to create situations where challenges to alertness are inevitable. Human physiology determines the limits of alertness maintenance. A number of factors which influence alertness have been well documented in both laboratory and field studies. These include time of day on the biological clock, duration, quality and timing of previous sleep periods, as well as inter-individual differences such as age and medical condition. These determinants of alertness directly and indirectly affect an individual's ability to be attentive to a work task.

Various approaches to improving alertness in the railway industry have been tried; however, each of these approaches presents its own difficulties:

- \* **Regulations of Hours of Work and Rest** do not and cannot take into account many of the physiological factors described above.
- \* **Disciplinary Action** fails to address the problem of alertness because it treats it as a disciplinary issue when it is primarily a physiological one.
- \* **Reliance on the "Iron Man" Syndrome** supposes that alertness can be maintained through sheer force of will. This is simply not the case.
- \* **Dependence on Cab Alerter Technology (Reset Safety Controls)** fails to ensure alertness because it is possible to operate these devices without conscious thought. It is also possible to drift into microsleeps between alarms, awakening only long enough to reset the device.
- \* **Collective Bargaining** fails to address the issue since alertness cannot be negotiated. There are physiological imperatives which must be respected if alertness is to be assured. Relegating these safety issues to the bargaining table invites incomplete and inadequate solutions.
- \* **Treating the issue as a medical problem** does not acknowledge the fact that the task of operating in a twenty-four hour environment poses significant challenges to all individuals, not simply those suffering from a medical disorder. For example, in CTI's survey of freight locomotive engineers in the test locations, 92% reported having been awakened by the cab alerter device at least once while operating a train.

Addressing the problem of train crew fatigue requires a fundamental change in cultural attitude so that the realities of the problem can be acknowledged and openly discussed, and a joint labour/management commitment can be made to systematically address the root causes of fatigue. This, as we will discuss below, was one of the primary accomplishments of the CANALERT '95 project.

## **Origin and Development of the CANALERT 195 Program**

Initially, the Steering Committee felt that, in order to properly respond to Transport Canada's directive, a new work-rest rule should be written to accomplish the following objectives:

1. That employees commencing duty be rested and alert,
2. that alertness be sustained throughout the duty period, and to the extent possible consistent with 1 & 2, the rule must
3. permit employees to meet their personal needs, and
4. the railways to meet service objectives and implement change.

After several meetings, it became apparent to the members of the committee that obtaining expert assistance in the field of human circadian sleep and alertness physiology would be beneficial in achieving the goals set for it by Transport Canada. Circadian Technologies, Inc. (CTI) was subsequently contacted and retained to assist the railways and unions in developing a viable approach to addressing the fatigue problem.

After consulting with CTI, the committee concluded that the problems of fatigue in the railways could not be addressed simply through the writing of a rule. Consequently, the goal of the committee became to "**develop, validate, and implement a set of fatigue countermeasures (technologies, rules, procedures and practices)**" which would accomplish the aforementioned objectives. The process of developing and testing this alternative to rule-making became known as

the CANALERT Project. CTI was subsequently retained to conduct various measurements of the effectiveness of the countermeasures, and to provide other research and consulting support related to the overall project.

The United Transportation Union elected not to participate in the project in 1995. Consequently, the study was conducted using solely locomotive engineers, although many conductors were supportive of the project as individuals.

### **Goals of the CANALERT Program**

CANALERT was conceived as a comprehensive program to address the issues of fatigue, or more precisely "impaired alertness," in the Canadian railway system. In CANALERT '95 a major goal was to develop a set of fatigue countermeasures which could be used to enhance alertness levels among a group of locomotive engineers without adversely affecting operations and to validate the effectiveness of these countermeasures through physiological, subjective, and operational measures. Another goal was to determine the relative alertness and mental workload stress levels of locomotive engineers running high speed passenger trains as compared to engineers running trains in freight service. A third goal was to perform an analysis of the schedule-induced fatigue level which might exist in passenger operations. To accomplish this goal, CTI performed an analysis of VIA Rail's schedules using its patented Circadian Alertness Simulation (CAS) software. This software predicts and models hour-to-hour alertness levels on any schedule and was used to identify those schedules which may be unduly fatiguing.

**The program was comprised of two phases. In phase I, a general analysis of the problem was undertaken and potential fatigue countermeasures were selected. Phase II was the pilot implementation and evaluation phase. This CANALERT '95 report, coming at the end of the second phase, summarizes the progress-to date.**

### **Freight Railway Countermeasure Development**

Pilot sites were selected during this phase, and support for the program was generated among employees, union leadership, and management. In order to design the countermeasures, it was necessary to gain a complete understanding of the operations in each of the chosen locations. This included in-depth analysis of operational practices and detailed terminal-wide surveys of freight engineers. The results of this survey were the subject of a previous report. Then the detailed implementation issues for each countermeasure were addressed so that, in phase III, the implementation of the countermeasures could proceed smoothly.

Critical to the success of this phase was the generation of support within the selected terminals. This required a long process of education of management and staff alike. Without support for the project at all levels, there would have been no successful implementation of fatigue countermeasures and no evaluation study.

### **Site Selection**

Two mountain subdivisions were selected which met all of the requirements for the pilot study. At CP Rail, the Laggan subdivision, operating from Calgary, Alberta to Field, BC, was selected. At CN Rail, the Alberta subdivision, operating from Jasper, Alberta to Blue River, BC, was used.

Each of these subdivisions is of approximately 135 miles in length, which resulted in running times ranging from about 4 to 8 hours in each direction, depending on train weight, horsepower, traffic flow, and direction of travel.

### **Countermeasure Development**

The detailed development of the countermeasures was a lengthy process involving many people with special areas of expertise including crew callers, road foremen, rail traffic controllers, locomotive engineer representatives, and railway management. As a result of this process the following countermeasures were developed:

### **Time Pool Scheduling**

Circadian time pools were developed as a means of ensuring predictability and regularity in the lives of locomotive engineers through the use of calling windows and scheduled days off, using circadian sleep-wake principles.

The time pools were designed to permit the volunteers to work their full complement of trips during each evaluation period. Locomotive engineers are limited to 3,800 miles per month by collective agreement. It was the intention of the program to compare engineers working 3,800 miles in an unscheduled environment to those same engineers working 3,800 miles in a scheduled environment.

To be assured of having enough trains to permit the volunteers to work their full complement of miles, the Circadian time pools were operated with fewer employees than would normally have been required to satisfy the flow of traffic. A "spare board" was used to meet operational needs.

Under the time pool concept, a locomotive engineer was assigned a specific pool, either "lark," "owl," or "cat." The time pool determined during what period of the day an engineer could be called for a work assignment from the home terminal. Larks were early-risers who were subject to call for duty periods commencing between 05:00 and 15:00. Owls were "night owls" who were subject to call between 13:00 and 23:00 and Cats (for cat-nappers) were subject to call between 21:00 and 07:00. This assignment start period was known as the "call window." The two hour overlap was referred to as the "extended call window" and served to permit an engineer who might not have been called during his normal window to be able to go to work prior to the calling of volunteers from the next time window. The calling windows were in effect from the home terminal only. Returns to the home terminal were governed by a combination of first in/first out sequencing as modified by the rest requirements described below.

In addition to the call window, there were three other windows (or zones) which related to each schedule:

The "protected zone" was the period during the day or night when an engineer on a given schedule would be most likely to experience fatigue in the absence of recuperative rest prior to a train run.

An engineer was permitted to take a return train without taking rest only if he could be home by the beginning of his protected zone. Otherwise, he was required to rest for a minimum of 3 hours at

the away-from-home terminal. This rest was called "Circadian Rest" and was taken during another zone known as the "recuperative zone." The recuperative zone was the period of time when it would be likely that an engineer on a given schedule would be able to sleep, thereby providing him with "recuperative rest."

Finally, a "special protected zone" was created to ensure that protection was available for engineers traveling during a time when fatigue might be a problem, even though Circadian Rest was not required. Engineers whose run would take them into their special protected zone were entitled to take a nap enroute, if they felt they needed one.

In addition to their regular time windows, volunteers were assigned a regular work schedule. Each engineer worked one day and was off the next. In addition, two assigned days off were built into the schedule each 28 days. These assigned days off were scheduled on an engineer's regular work day. Consequently, they resulted in approximately three days off, since the day off was preceded and followed by the engineer's recuperative days. The days off were also scheduled to allow the volunteers one complete weekend off out of every 28 days.

Engineers were permitted to book rest at the away-from-home terminal according to the terms of the existing collective bargaining agreement. This allowed engineers to book up to 8 hours rest. Booking rest was not permitted at the home terminal since the schedule provided for ample rest before being sent out again.

At the away-from-home terminal, determination as to which engineers required Circadian Rest was made by using the estimated enroute time of the next train for which the volunteer was eligible. If this train would arrive home after the beginning of the protected zone, then Circadian Rest would be required. Often the requirement for rest would not be fulfilled in time to take a given train; in this case another engineer (from a later time pool) would be assigned to take the train and the Circadian volunteer would take the next train after completion of the mandatory rest period.

### **Bunkhouse Improvements**

Locomotive engineers frequently complain about their inability to get good quality sleep since the bunkhouses are located near the railway tracks and are subject to disturbances from passing trains, whistles, noise in the halls, daylight entering the rooms, etc. Getting good quality daytime sleep was reported as being particularly problematic.

To address these issues, we decided to improve one of the bunkhouses used in the study. Consequently, six rooms at the Blue River bunkhouse had the following improvements made:

- \* Interior walls with sound-reducing tiles, carpeting, silent light switches, telephones with soft bells, thick doors, and weather-stripping were installed to reduce the ambient sound in the bunkhouse rooms.
- \* Blackout curtains were installed on the windows to completely block out daylight.
- \* Masking noise generators were installed in each room. These devices provided an array of sounds ranging from surf to wilderness to white noise. They were intended facilitate sleep onset and reduce arousal by masking the sound of passing trains and other noises in the vicinity

of the bunkhouse.

### **Napping Facilities and Policy**

By giving locomotive engineers the opportunity to take a short nap, either before a run, or enroute while in sidings awaiting passing trains, crews were allowed to take steps to improve their overall alertness on the job without disrupting traffic flow.

### **Enroute Napping**

The locomotive engineers typically spent a significant amount of time in sidings. Often several delays of 20 minutes or more were experienced on a typical run. Because of the frequency of these delays combined with the unpredictable nature of the traffic flow, it was determined that controlled napping enroute would be a feasible fatigue countermeasure.

When an engineer entered a siding where a delay was expected, he was permitted to take a short nap (approximately 20 minutes). He would notify Rail Traffic Control and switch to a special radio frequency. Napping was also permitted on the main line with Rail Traffic Controller (RTC) concurrence. This situation could arise following a broken rail or some other significant delay to traffic on the main line. Napping was not permitted where there would be a risk of the train creeping away due to the grade of the track. As such, napping was not permitted west of Stephen on the CP Laggan subdivision.

Engineers were provided with mattresses and blindfolds to aid napping, and "nap timers" which were used to awaken them after the nap period. There were three categories of nap: Opportunity, Negotiated, and Entitled. Most naps were Opportunity naps, that is, naps taken as the opportunity arose, usually in sidings and without special arrangement with RTC. The frequent stops in sidings made napping opportunities plentiful.

The two other categories, Negotiated and Entitled naps, were related to the time of day during which the train run was taking place. If a run took an engineer into his protected or special protected zones and the engineer felt he needed it, he was permitted to request a nap at any point during the run. The exact time and location of the nap was negotiated with the RTC, thus the terming of this nap as "negotiated." Were the engineer and RTC to fail to agree on an appropriate time for the nap when the engineer was entitled to one (based on the time of the run), the engineer was authorized to instruct the controller to line him into a siding for a nap. In all cases, however, engineers and RTCs were able to agree on a mutually convenient time for requested naps; no "entitled" naps were taken throughout the entire project. In all, only five "negotiated" naps were taken throughout the project. All the others were "opportunity" naps.

In order to permit implementation of the napping countermeasure, an exemption to CROR Rule I 10 requirement to inspect passing-trains was granted by Transport Canada. CROR Rule I 10 states that train crews will inspect passing trains whenever practicable.

### **Terminal Napping Facilities**

In addition to the enroute napping countermeasure, it was determined that terminal napping prior to a delayed departure could be an effective fatigue countermeasure, and it was decided to create

special Terminal Napping Facilities (TNF) at the Calgary and Jasper home terminals for delayed crews.

One room in each location was equipped with comfortable reclining chairs and/or couches which could be used by a delayed crew until it was time to depart. A telephone was installed in each room so that the crew caller could inform the engineer when it was time to board his train. The use of the terminal napping facility in conjunction with the enroute napping policy ensured that all non-productive time was available to be used in alertness recovery through napping.

### **Locomotive Cab Audio System (LCAS)**

Much in the same way as a car radio provides stimulation to a tired motorist it was decided to provide locomotive engineers with an opportunity to listen to music or other programming so as to assist them in remaining alert during the more monotonous periods of a run, such as when climbing a long grade. At the same time, we sought to provide sound attenuation to reduce disturbances and hearing damage from engine noise and an intercom function to enhance in-cab communication between the engineer and conductor.

In consultation with CTI consultants, David Clark Company of Worcester, Massachusetts developed a battery-powered custom intercom/music program system for use in the locomotive cab. Additionally, special headsets with high-fidelity earphones were manufactured by David Clark Company in order to facilitate the music countermeasure. Music was provided from an attached tape cassette player. These headsets provided an average of 23 decibels noise reduction.

In addition to allowing the engineer to listen to music, the system was also connected to the cab radio transceiver and contained an intercom for communicating with the conductor, who was also equipped with a headset.

Whenever the radio was engaged, either in transmit or receive mode, the audio program would automatically be muted by the system, much as a pilot's announcement will mute the program in an airline passenger cabin. This muting feature ensured that the engineer could hear all communication from the RTC.

The engineer and conductor could speak to one another by simply speaking into the microphone; no push-to-talk was required. If a music program was in use, in-cab conversation was accomplished by speaking over the program.

### **Lifestyle Training Program and Individualized Counseling**

To complement the other countermeasures with education about human circadian physiology and coping strategies for shift-workers, CTI developed a four-hour training program, "Managing a Railroad Lifestyle." The program was designed to acquaint the volunteers with information relevant to performing work in a round-the-clock railway environment. This training program, which was provided to all locomotive engineer volunteers and their spouses/partners, covered issues ranging from biological clocks to sleep to nutrition and family issues. In addition to providing general education relevant to workers on erratic schedules, another goal of the program was to maximize the effectiveness of the countermeasures. The information imparted by the program was

specifically tailored to explain and introduce the fatigue countermeasures.

As a supplement to the Lifestyle Training Program, volunteers were encouraged to meet with a sleep specialist to discuss any problem they might have been experiencing in adjusting to their new schedules or in implementing any of the counter-measures. These confidential sessions were conducted either at the home of the volunteers or at a location of the volunteers' choosing.

## Study Design

In evaluating the fatigue countermeasures in freight operations, there were three key questions we sought to answer:

1. Did each of the countermeasures work operationally?
2. Did the combined set of countermeasures result in reduced fatigue and increased alertness?
3. How did each countermeasure contribute to the overall effect on locomotive engineer alertness?

Volunteers for the freight study were recruited through the normal bidding process. To volunteer for the project a locomotive engineer simply bid the chosen subdivision. The commitment was for six months, which included one month of baseline testing, three months of countermeasure implementation and adaptation, and one month of post-countermeasure testing. The sixth month of the pool would be available for those who wished to remain in the program after the completion of the countermeasure evaluation testing. Of the forty freight line volunteers, 16 were assigned to the "lark" time pool, and 12 to each of the "owl" and "cat" pools.

Locomotive engineer volunteers kept track of their sleep-wake-work patterns in a Sleep-Wake-Work Log. Each day throughout a one month period during baseline (May) and another one month period during post-countermeasure testing (September), the engineers recorded their times off duty (awake, asleep) and times on duty (running train, not running train) in 15 minute intervals. In addition, they rated the quality of their sleep at home. The volunteers' activity/rest patterns were also continuously recorded by wrist activity monitors throughout each of the test months and served as an objective validation of the Sleep Log data.

Each volunteer agreed to be "wired-up" to a portable EEG (brain wave) recorder for three randomly-selected round trips during both a baseline test period as well as during a post-countermeasure testing period. No prior notice of a "wire-up day" was given so that the engineers could not specially prepare themselves for the day of study. Thus, we obtained a realistic snapshot of their lifestyles and alertness levels.

On the three randomly-selected work days within each testing month, a detailed physiological assessment of each volunteer was undertaken before, during, and after each run. Test runs were usually round-trips starting at the home terminal (Calgary or Jasper). Round-trips consisted of an outbound run ( to an away-from home terminal) and an inbound run (back to the home terminal).

Electro-physiological measures were continuously recorded during the entire trip using portable

recorders. An electrode "Wire-Up" was performed at the home terminal prior to the trip, starting one hour before the train call time. The electro-physiological recordings were used for measuring drowsiness, analyzing microsleeps, analyzing naps during the runs, for scoring sleep at the away-from home terminal and for evaluating pre- and post-ran alertness levels using scoring of alpha brain wave levels.

Sleep episodes in the away-from-home terminal bunkhouse, as well as any naps taken in the sidings were analyzed in all volunteers wired up with EEG/EOG electrodes. Sleep architecture was also analyzed, with particular attention paid to measurement of disruption in sleep continuity (sleep fragmentation).

The protocol for data collection at VIA Rail was similar to that used for the freight study. Ten locomotive engineer volunteers were recruited from the high speed corridor operating between Quebec City and Montreal. Two daytime round trips per engineer were recorded over a two-week period. During the runs, electro-physiological data was continuously recorded. As with the freight study, VIA volunteers were asked to complete Sleep-Wake-Work Logs and wear activity monitors during the two-week period of the study.

### **Evaluation of Baseline Level of Freight Locomotive Engineer Alertness**

Prior to implementation of the countermeasures, the alertness levels of the volunteers in each location was determined during a baseline evaluation period.

On-duty alertness measures showed a clear time-of-day effect. Alertness was highest for daytime departures and lowest during the early part of the night. On arrival, the volunteers were most sleepy in the latter part of the night and early morning hours. Analysis of sleep logs indicated that while the total amount of sleep was not different from that of the general population, with sleep per day averaging approximately 7 1/4 hours, sleep was frequently split into two or more episodes per day and temporary sleep deprivation was a problem on some working days. While running trains, extreme sleepiness was particularly observed at night. Engineers in Calgary reported that they nodded off in 46% of the outbound runs and in 37% of the inbound runs. Jasper engineers reported fewer runs with nodding-off episodes, indicating episodes in 29% of the outbound runs and 30% of the inbound runs.

Episodes of drowsiness were documented by EEG at all times of day and night, with an increased preponderance during nocturnal hours in both Calgary and Jasper groups. In addition, in Jasper a late afternoon peak in alpha bursts was observed. Severe bouts of drowsiness were sometimes observed within 3-4 hours of commencing duty even after more than 24 hours of rest prior to duty.

On other occasions locomotive engineers were able to work up to 16-18 cumulative hours over a 24 hour period without any evidence of microsleeps or excessive drowsiness. This evidence brings to question the usefulness of an hours of service regulatory approach to managing train crew fatigue.

The data illustrate that fatigue is a problem in both test locations. Calgary engineers appeared somewhat more fatigued and had more workload stress than those in Jasper according to several of

the measures. Heart rate variability was significantly lower during the outbound runs of the Calgary group as compared to the Jasper group, suggesting a higher mental stress level when running trains between Calgary and Field. In fact, this subdivision has a very steep hill to descend, long runs, heavy trains, and much single track, all of which may have contributed to the increased workload stress that was detected. In addition, commuting to and from work was found to be more demanding in Calgary than in Jasper with the majority of locomotive engineers in Calgary having a 15 to 30 minute drive, while most Jasper engineers walk to work in under 15 minutes.

Overall the alertness and other physiological measurements suggested the existence of a trend toward higher alertness and lower workload stress in the Jasper group of volunteers as compared to the Calgary group during baseline testing. Consequently, it could be anticipated that fatigue counter-measures might be more effective in Calgary since there was more of an opportunity for improvement.

## **Evaluation of Individual Fatigue Countermeasures**

### **Time Pools**

The time pools were extremely popular with the volunteers with 80% of them rating the time pools as reasonably or extremely effective at increasing alertness and decreasing fatigue while both on and off duty. Most engineers (88%) reported adjusting to the transition to time pools in little or no time. A similar number (85%) found that the time pools improved their family and social life. Volunteers reported that a principal benefit of the time pools was having the knowledge of when they were going to work. This enabled them to better plan their rest in order to be prepared for their trips. In focus groups they also reported that not being "on call" at all hours allowed them to relax when off duty, rather than being constantly on edge awaiting the next call.

Over 78% of the locomotive engineers found that the time pool decreased their need to book off for personal time. This finding was confirmed by a large decrease in absenteeism.

According to data provided by railway management, absenteeism on the Laggan subdivision at CP Rail fell more than 60% from approximately 8.1% in 1994 to 3.2% during the CANALERT project. At CN the absenteeism rate on the Alberta subdivision was reduced from 5.7% in 1994 to 2.5% during the CANALERT project. This represents a 56% reduction in the rate of missed calls at CN, where the absenteeism records for sixteen of the twenty volunteers were improved overall. Only two of the twenty locomotive engineers had more sick days during the CANALERT program than during the control period and only four volunteers missed more calls during the CANALERT project.

This reduction in absenteeism was a positive effect of the program. It led to more predictable crew management, which had significant benefits for operational efficiency.

The "cat" time pool was found to be the most difficult to manage by the volunteers, due to the large amount of night runs involved, although even here, 70% reported adjusting to the new schedule in little or no time and 60% reported the time pools as reasonably or extremely effective at increasing alertness and decreasing fatigue on-duty.

Operation of the time pools caused no significant problems from the railway standpoint. Predicted increases in deadheading at CP Rail never materialized and crew availability was never a problem due to the availability of crews from the spare board.

CN management in Kamloops, British Columbia, reported the existence of the CANALERT program at CN significantly reduced the number of operational problems experienced on the subdivision by an estimated 60%. This improvement was attributed to the following factors:

- \* predictability: the RTC knew when crews would be working
- \* regular pattern: availability of crews followed a repeating pattern
- \* better communication: the relationship between the engineers and RTCs was improved, allowing for joint problem-solving.

A complete evaluation of the physiological effectiveness of the time pools independent of the effects of other counter-measures (i.e., no napping, no headsets, no bunkhouse improvements) was only possible to conduct in the Calgary pool. Alertness pre- and post-trip and alertness while running trains was improved according to subjective measures. The quality of off-duty sleep at home was significantly improved in the post-countermeasure condition. In the post-countermeasure condition, there was no significant change in the minimal levels of chronic sleep deprivation observed.

**Conclusion** - The time pool system increased the regularity and predictability of work periods while permitting continued efficient crew utilization and undisrupted railway operations. The time pools offered significant benefits because they resulted in greatly reduced absenteeism, improved subjective alertness, improved sleep quality, greater job satisfaction and increased predictability for railway planners. Both management and the volunteers found this approach to ensuring work-rest regularity to be operationally feasible. All parties indicated that they could have easily continued utilization of the time pools indefinitely.

### **Bunkhouse Improvements**

There was unanimous approval of the bunkhouse improvements. In the subjective survey, 100% of the volunteers in Jasper felt that the improvements made a noticeable overall difference in the quality of rest they were able to get in the bunkhouse. Furthermore, with six improved rooms in the Blue River bunkhouse, there was always a room available for a CANALERT volunteer wishing to rest.

The restorative value of sleep was significantly enhanced at the improved bunkhouse (Jasper group) during post-countermeasure testing as compared to baseline. Sleep duration was similar in both testing conditions. Time to fall asleep was significantly shorter (8.8 minutes during baseline versus 4.5 minutes during post-countermeasure testing). Sleep efficiency increased from 88% to 94%. The percentage of Slow Wave Sleep increased significantly from 9.1% to 21.7%. No statistical differences were found for REM sleep, or any of the sleep fragmentation measures.

For the unimproved bunkhouse (Calgary group), the statistical analysis did not reveal any difference

in sleep quality between baseline and post-countermeasure measurements.

**Conclusion** - Since improved sleep quality during post-countermeasure testing was found in the Jasper group but not in the Calgary group, we can conclude that these changes are mainly related to the bunkhouse improvement countermeasure and not to any indirect effect of other countermeasures.

### **Napping Facilities and Policy**

The on-duty napping countermeasure was initially considered one of the more controversial of the countermeasures; however, its operation proved smooth and issue-free. If anything, the countermeasure was used less frequently than had been anticipated. Most naps were taken as the opportunity arose, usually in sidings awaiting passing trains. The suspension of Rule I 10 for napping crews enabled them to remain in the cab rather than having to exit to inspect trains.

No problems with the napping countermeasure were reported by either the railways or the volunteers during the entire countermeasure period (late June through end October, '95). In the post-countermeasure survey, only about 20% of the volunteers reported not using this countermeasure at all, while 54% of engineers took "as available" naps while working every few runs or more frequently.

In the baseline stage, 24 volunteers reported that they would have wanted to take a nap had it been permitted. In the post-countermeasure stage, only 15 engineers actually napped.

Nodding-off was reported to a lesser extent during post-countermeasure testing (napping permitted) than during baseline. Runs with reported nodding-off decreased from 38% to 30% in the Calgary group and from 23% to 16% in the Jasper group.

**Conclusion** - Enroute napping was judged to be effective for enhancing alertness by a majority of the engineers. Although the opportunity to nap during train stops was desired by many engineers before introduction of the countermeasures, it was only utilized by approximately half of the volunteers. This may be, in part, a sign of a reduced need for on-duty naps 'due to the effectiveness of the entire countermeasure set, but also to some extent reflects the fact that the locomotive engineers did not always use the countermeasures available to them. When given the opportunity to nap, nodding-off was reported to a lesser extent than during baseline. In addition, this countermeasure was found to be non-disruptive to railway operations.

### **Locomotive Cab Audio Systems (LCAS)**

The audio system countermeasure also proved extremely popular with the volunteers. Only two volunteers reported never using this countermeasure. It was later learned that one of the two was inadvertently not provided with a headset. Fifty-four percent (54%) of the volunteers reported using this countermeasure as much as possible, while another sixteen percent (16%) reported using it somewhat frequently.

Volunteers overwhelmingly (92%) found the headsets to be helpful in reducing engine noise, while 89% found them useful in facilitating communication with the conductor and rail traffic controllers.

Eighty-four percent (84%) of the volunteers reported that listening to music on the headsets was useful in enhancing alertness and reducing fatigue, with 54% describing them as extremely useful in this regard.

We assessed the effectiveness of headset availability by using modified Post-Run Logs. When using headsets, the number of runs with reported nodding off was drastically reduced. In fact, nodding-off was only reported for one inbound run using headsets and on none of the outbound runs. Alertness while running the train was assessed by Visual Analog Sleepiness Scales. The results show that subjective alertness was significantly increased when using headsets during both the outbound and inbound runs, as compared to runs without headsets.

**Conclusion** - When using headsets with music programming, alertness while running the train was significantly enhanced. The volunteers also overwhelmingly supported the countermeasure. Operationally, the units were found to reduce noise-related stress, improve engineer-conductor communication as well as communication with Rail Traffic Control.

### **Lifestyle Training Program and Individualized Counseling**

The lifestyle training program was well received by the volunteers. Most spouses did attend and participated fully in the 4-hour session. In addition, counseling sessions were conducted about two months after countermeasure implementation during the volunteers' off-duty time. The sessions, which 25% of the volunteers requested, lasted approximately one hour.

Approximately half the volunteers indicated in the post-countermeasure survey that they had used the information provided in the lifestyle training program to make changes in their lifestyle and sleeping strategies. These results indicate relatively high levels of compliance, given that it was achieved with only a single half-day session.

**Conclusion** - Lifestyle training was judged to be effective by the volunteers. Inclusion of spouses was felt to be of great benefit. However, because the program provided only a single four-hour session, and there was no ongoing program to reinforce the training it provided, the long term value was limited.

### **Effectiveness of Combined Set of Fatigue Countermeasures**

Overall, and particularly in the Calgary group, alertness was higher during post-countermeasure testing as compared to baseline. This finding is based on statistically significant differences which were found for the test sessions at arrival from the round-trip as well as for the test sessions at arrival from the outbound runs and at departure for the inbound run. In Jasper, the improvement was less pronounced, which is consistent with the observed trend of a slightly lower sleepiness level prior to the implementation of the countermeasures than was found in Calgary.

During the post-countermeasure testing, the number of runs with at least one reported nodding-off episode was reduced by 15-30% in both groups. This overall trend of decreased sleepiness and increased subjective alertness was also noticeable when breaking the data into time windows as were used in the time pool program. However, for runs departing in the "Cat" window, no

statistically significant changes in alertness were found.

The assessment of microsleeps and drowsiness by means of EEG measures through automatic and visual scoring revealed considerable inter-individual variation. It was, therefore, not possible to demonstrate statistically significant differences in group data. Nevertheless, examination of individual records of locomotive engineers was most revealing. It demonstrated that whether the engineer used the available countermeasures was a major factor in determining whether episodes of severe drowsiness and microsleeps were observed.

### **Effects of Countermeasures on Locomotive Engineer Health**

Physical health was evaluated using two scales: Gastrointestinal (digestive) disorders and cardiovascular disorders - both categories of medical disorders that are typically associated with shiftwork. During baseline, the engineers complained mainly of digestive disorders. During post-countermeasure testing, the survey showed a significant improvement in health. The overall score for the gastrointestinal (digestive) scale dropped significantly from 14.4 to 12.6. A clear reduction in the frequency of digestive problems was observed: Disturbed appetite was reduced from 40.5% to 5.4%, the rate of heartburn or stomach-ache was reduced from 16.2% to 2.7%, and flatulence was reduced from 27% in baseline to 8.3% in the post-countermeasure condition. Constipation or diarrhea dropped from 10.8% to 0%. Still, 18.9% of the volunteers reported that they have to watch what they eat in order to avoid stomach upsets, although the percent who says that it is never a problem increased from 40.5% in the baseline to 54.1%. Overall diet improved as well, with 28% of the volunteers reporting having lost weight and 38% reporting that they used the information presented to them during the lifestyle training to change their eating habits.

### **Comparison Between Passenger and Freight Locomotive Engineer Alertness, Mental Workload and Health**

In order to compare locomotive engineer alertness in passenger versus freight operations, CTI performed a study of alertness on the high-speed VIA corridor between Quebec City and Montreal. In addition to measuring alertness levels on the high-speed line by methods similar to those described previously, we also evaluated job stress/workload levels as compared to freight operations at Jasper (CN) and Calgary (CP).

#### **Alertness While Running the Train**

Ten VIA locomotive engineers were recruited from the high-speed passenger line running from Quebec City to Montreal and back. They participated in testing during two round-trips in August, 1995 using the same set of physiological measures as were used in the freight study. Daytime runs departing between 0630 and 1400 were selected for recording. One-way trips lasted approximately 3 hours. A round-trip lasted between 7 and 9.8 hours depending on the amount of time spent at the away-from-home terminal in Montreal. Arrival time back in Quebec City was no later than 2100.

Since two engineers were sharing each run with a switch at the midpoint in Drummondville, the actual time an individual engineer spent running the train in each direction was approximately 1.5 hours. Only one engineer per train run was tested.

A trend of progressively increasing sleepiness during the course of the passenger train run was found in the group means for the outbound and even more pronounced for the inbound run-leg. For all portions of the run, subjective sleepiness was significantly higher on the inbound run as compared to the outbound run.

EEG analysis confirmed that a few alpha-bursts occurred during passenger train runs. When they happened, they occurred only during the inbound run-leg. The alpha bursts occurred mainly when the other engineer was at the controls and the volunteer was not running the train. This analysis confirmed subjective nodding-off reports which were recorded by the volunteers.

Nodding-off while running the train was reported much more frequently by the freight engineers than by the passenger engineers. Freight engineers reported during baseline that they nodded-off during more than 30% of the outbound and inbound runs, the passenger engineers reported nodding-off only for one outbound run (5.5%) and three inbound runs (17.6%). Alpha-bursts were also detected in the EEG recordings much more frequently in freight engineers than passenger engineers.

The comparison between mean sleep duration in the freight engineers and in the passenger engineer group revealed that the passenger engineers slept, on average, approximately one hour longer per day than did the freight engineers. Mean sleep duration of the passenger engineers was 8.2 hours as compared to 7.3 hours for the freight engineers.

### **Mental Workload/Stress and Heart Rate Variability**

Mental workload (often referred to as job stress) was evaluated by using heart rate variability as a measure. Low heart rate variability is associated with higher stress and high heart rate variability is associated with lower stress. Heart rate variability was significantly decreased when passenger locomotive engineers were running trains as compared to not running trains, indicating the increased mental stress of the task.

The passenger locomotive engineers showed lower heart variability than the Jasper freight engineers, indicating greater mental workload on the passenger runs than on the freight runs out of Jasper. This difference was statistically significant for the inbound leg of the passenger train runs and almost reached a significant level for the outbound runs. Heart rate variability of the passenger locomotive engineers during the inbound run was as low as that of the freight engineer group in Calgary.

The results indicate that the overall workload stress of the passenger engineers is higher than that of the freight engineers in Jasper but lower than that of the freight engineers in Calgary.

### **Health Evaluation**

Health was evaluated on two scales, one for digestive (gastrointestinal) and one for cardiovascular disorders. The freight engineers complained significantly more about digestive disorders than the passenger engineers, as was expected given the more irregular life style of freight engineers. No differences between the groups were found for the cardiovascular scale. Both groups had very low scores of around 10 on a scale ranging between 8 and 32.

## **System-Wide Analysis of Engineer Alertness on VIA Rail Schedules**

To assess the overall risk of schedule-induced fatigue across the VIA Rail system, a computer simulation of human alertness, developed by CTI, was used. This simulation software incorporates known determinants of alertness to predict, for any work-rest schedule, the time profile during each trip when an individual is likely to be drowsy and when he or she is likely to be alert. This patented software system is called **Circadian Alertness Simulator-** or CAS. CAS enables a large number of schedules or potential schedules to be analyzed in a quick and efficient, objective manner.

### **Objectives**

The objectives of the study were to:

1. Obtain an estimate of the percentage of schedules where fatigue risk occurs, and determine in which schedules this risk could be avoided by improved scheduling procedures.
2. Provide a representative set of case study examples which demonstrate the types of problems that exist, and document the causes of the fatigue risk induced in each case study.
3. Determine the particular types of schedule sequences where fatigue risk most often occurs.
4. Suggest potential applications of fatigue countermeasures to optimize alertness on the schedules identified as being at risk.

### **Definition of Fatigue**

For purposes of the study, we used the following definitions of varying fatigue levels:

#### No Schedule-Induced Fatigue (No SIF)

A schedule where the simulator predicted no drowsiness was classified as a having "no schedule-induced fatigue." This does not mean that an engineer will definitely not experience fatigue on any given run. It simply means that the schedule itself is not one which induces fatigue independent of other causes.

#### Mild Schedule-Induced Fatigue (Mild SIF)

A schedule where 0.1 - 19.9% of the time was spent at a drowsy level was classified as having "mild schedule-induced fatigue."

#### Moderate Schedule-Induced Fatigue (Moderate SIF)

A schedule where 20 - 39.9% of the time was spent at a drowsy level was classified as having "moderate schedule-induced fatigue."

#### Severe Schedule-Induced Fatigue (Severe SIF)

A schedule where 40% or greater of the time was spent at a drowsy level was classified as having "severe schedule-induced fatigue."

The VIA system consists of 20 terminals. From these 20 terminals, VIA runs 175 schedules in a given period. CAS analysis based on the above assumptions showed that of the 175 schedules in

the system, 140 schedules (80%) had no schedule-induced fatigue risk, 18 schedules (10%) were classified as having a mild" fatigue risk, 15 schedules (9%) were classified as having "moderate" fatigue risk, and 2 schedules (1%) were classified as having "severe" fatigue risk.

The overriding factor leading to schedule-induced fatigue risk in the VIA system was that locomotive engineers are required to run trains at night. This problem cannot be avoided. However, by invoking pre-duty napping strategies where possible, modifying their sleep-wake schedules when feasible, and having a commitment to making prudent use of their off-duty time between train runs, engineers will be able to effectively reduce the fatigue risk on those runs that may be problematic.

## **Overall Conclusions**

CANALERT '95 was by far the largest and most comprehensive investigation of alertness, sleep and fatigue that has ever been conducted in locomotive engineers, and was the first study to implement and evaluate a comprehensive set of fatigue countermeasures in actual operating conditions. We received valuable support and creative input from many locomotive engineers, union officials, local supervisors and managers and executives from CP, CN, VIA Rail and Transport Canada, and the project was given the highest priority and attention at all times.

The results and insights gained in this project should, therefore, be credited to the many who participated and gave their full support to the Circadian Technologies research and consulting teams.

The results of the CANALERT'95 project show that it is feasible to implement in railway operations a specially designed set of fatigue countermeasures based on alertness and sleep physiology, and thereby achieve broad ranging improvements in locomotive engineer alertness, morale, health and absenteeism, without impeding traffic flow or other operational factors.

### **Fatigue is a Real Issue in the Railways**

The data collected in this study and our direct observations can leave no doubt that locomotive engineer fatigue is a frequent occurrence in railway operations.

### **Hours of Work and Rest Regulations Cannot Guarantee Protection Against Fatigue**

The results of this study raise serious doubts as to the efficacy of any practicable hours of work and rest regulation at eliminating the risk of fatigue. Engineers were detected to have drowsiness episodes while operating locomotives shortly after commencing duty, especially at night, even after extended periods of prior rest off-duty of 24 hours or more. And yet, under other circumstances, locomotive engineers were found to be without any measurable impairment after extended hours on duty.

### **Fatigue Countermeasures Can Be Successfully Implemented in Railway Operations**

The application of the fatigue countermeasures was, by all accounts, a clear success. All implementation issues were satisfactorily addressed, and both the locomotive engineers in the freight pools and the railway operations personnel (crew calling, train dispatch, area management) found the increased predictability and regularity of the countermeasure system to improve not only

operating conditions but also their day-to-day lives. The sharply reduced absenteeism levels increased the efficiency of operations, and the increased reliability in engineer availability made the crew calling task less difficult.

### **Circadian Sleep and Alertness Principles are Effective in Addressing Employee Fatigue in Railway Operations**

The operationalized fatigue countermeasures based on circadian sleep and alertness principles proved to be as effective at enhancing alertness as they have been demonstrated to do in the controlled conditions of the scientific laboratory. The study also pointed out a number of areas where we could enhance the design of the countermeasures or supplement the program with additional countermeasures. In particular the results suggest that the staffing and the timing of the Cat Time Pool may need refinement, since the greatest problems in maintaining alertness were found in this group.

### **Countermeasure Effectiveness Requires Countermeasure Compliance**

The evidence we gathered from the CANALERT '95 freight study demonstrates that the fatigue countermeasures which were introduced in the freight operations were effective both as a complete set and as individual countermeasures. However, in examining the EEG data it became clear that on certain trips an occasional individual showed seriously impaired alertness even after the Countermeasure set had been implemented, because the individual did not take advantage of the countermeasures (such as napping) that were available to him.

An examination of these cases underlined an important truth: Certain fatigue countermeasures can only be effective if the individual utilizes them. This emphasizes the importance of an ongoing education and culture-modifying effort to encourage full utilization of fatigue countermeasures.

### **Maintaining Alertness is a Joint Responsibility of Employees and Management**

This project demonstrated that management can, by introducing fatigue countermeasures, remove many of the operational impediments the engineers face in preparing adequately to be alert and remain alert on duty. As a result, engineers are given opportunities they never had before to improve their level of alertness, their performance and their health.

To be successful in introducing fatigue countermeasures requires collaboration between employees and their unions and management. No one group holds all the answers or is the source of all the root causes of fatigue. Alertness cannot be mandated; it must be reached by the systematic identification and removal of the root cause factors and obstacles which render employees fatigued.

## **Recommendations**

The recommendations made by CTI in this report are summarized below:

### **Provide Regular and Predictable Duty Periods**

In light of the findings relating to the operation of the time pools, CTI recommends the adoption of scheduling systems which will provide regular and predictable duty periods for crews. Time pools are one such system, where assignment to specific trains is not required. However, while time pools may be viable options in some locations, they might be difficult to implement in others due to

such factors as uneven or erratic traffic flow. Nonetheless, whether it be through assignment of crews to specific scheduled trains, time pools, or a combination of the two, the benefits of providing a more regular lifestyle, which permits planning of rest as well as work, cannot be overstressed.

### **Require Rest After Outbound Night Runs and Prior to Overnight Return Runs**

The study data showed that even when they were reporting themselves as being extremely fatigued, certain volunteers did not stop to take a recuperative nap although this was a key fatigue countermeasure available to them. CTI recommends that a significant period of time be available for sleep at the away from home terminal under circumstances where train crews have run an outbound train during the latter part of the night (e.g., from 2 a.m. through 6 a.m.) or where their return trip will involve running a train at any time during this same period.

### **Implement Napping Strategies System-wide**

The study has shown that napping can be permitted for train crews in sidings without adversely affecting system operation while providing a means for significantly improving the alertness of train crews. CTI recommends that strategies be developed to permit both enroute and terminal napping as an alertness recovery measure. We also recommend that napping train crews be exempted from train inspection responsibilities, and that reclining seats be installed in new locomotive cabs (and as seats are replaced in existing ones) to facilitate on-board napping.

### **Modify Bunkhouse Rooms for Improved Daytime Sleep**

In light of the findings of significantly improved sleep in the improved bunkhouse in Blue River, CTI recommends that bunkhouse and/or hotel rooms utilized by locomotive engineers be modified to ensure a quiet, dark environment, to aid in improving daytime sleep.

### **Install Locomotive Cab Audio Systems (LCAS)**

Cab intercoms have been shown to be effective at enhancing alertness and improving communications. CTI, therefore, recommends that all locomotives be equipped with cab intercoms interconnected to the radio transceiver, and that all train crews be provided with sound-attenuating headsets. The cab intercoms should be equipped with an auxiliary input jack to which privately-owned tape cassette recorders, and/or Compact Disc players can be attached.

### **Conduct and Extend Lifestyle Training Program**

CTI recommends that a 4-hour lifestyle training program be initially conducted for all running trades personnel, and that this program be reinforced at regular intervals through written communication, small-group sessions, audio and video programming, etc. Spouse participation is essential to maximize the effectiveness of this program.

### **Train RTCs and Crew Callers in Strategies**

To ensure that fatigue countermeasures can be implemented smoothly at railway locations, we recommend that Rail Traffic Controllers and Crew Callers be given instruction in the philosophy, as well as the operation, of any of the various fatigue countermeasure programs which may be implemented.

### **Investigate and Rectify Problem Schedules at VIA Rail**

Based on our analysis of locomotive engineer schedules CTI recommends that VIA Rail institute a process for identifying and modifying crew schedule run sequences which pose special risks of fatigue by incorporating Circadian Alertness Simulation™ methodology into the schedule generation and evaluation process. Using this approach, we recommend that VIA Rail develop crew scheduling rules which optimize railway safety, productivity, and locomotive engineer health.

In addition, we recommend that VIA Rail develop effective railway engineer lifestyle training packages which are specific to the needs of locomotive engineers with differing circadian types, and incorporate advice on how to prepare for schedule/run sequences which present a risk of schedule-induced fatigue.

### **Areas for Further Consideration**

The following four items, while not dealt with directly in this study are, in our opinion, worthy of further consideration:

#### **Locomotive Cab Improvements**

We suggest that the knowledge of the precise characteristics of alertness, drowsiness and microsleeps in railway engineers gained from the CANALERT '95 project be used to create a realistic simulation of nighttime runs (when the risk of microsleep episodes is highest), and that potential improvements to the locomotive cab, which would enhance alertness and specifically reduce the risk of microsleeps, be evaluated. The CANAC locomotive simulator at Gimli may be a useful resource for conducting these studies.

#### **Alternatives to Mileage-Based Pay System**

CTI believes that the present system of mileage-based payment may encourage freight crews to run their trains under conditions when they are less than fully alert, leading to impairment of safety. We, therefore, recommend that the railways and unions investigate the possibility of moving to a method of payment that would remove the incentive for individuals to **push** themselves beyond their limits.

#### **Provision of Two Qualified Employees to Run Trains**

In light of the frequent requirement to run trains through the night and the long tours of duty required of freight engineers, we suggest that having both members of a crew qualified to handle the controls of the locomotive is an idea worthy of investigation. The second employee could relieve the locomotive engineer from time to time, as well as provide an added safety margin for any unplanned events.

#### **Explore Alternatives to Hours of Duty and Rest Regulations**

Given the difficulty of drafting regulations that can address all of the variables that affect alertness in railway operations, we believe it would be worth investigating the feasibility of a performance-based approach to regulating this aspect of safety. Transport Canada would then audit compliance and would utilize performance measures as an aid in determining whether the railways were meeting the desired goals. Thus, the railways would be responsible for demonstrating success

through objective measures of safety.

The results of the CANALERT '95 study demonstrate that while solutions to the problems of fatigue exist, there is no "magic bullet" which will easily solve all of the problems. Rather, a combination of interventions are required to address the problem. One countermeasure alone isn't enough. One training session alone is not enough. Different terminals have different problems. Passenger operations require different implementation strategies than freight operations. Each special situation must be addressed individually if the desired results are to be achieved.

The opportunity now exists to maintain the momentum that has been created. The challenge remains for management, labour, and the regulatory bodies to sustain and build upon that momentum to establish a new, breakthrough level of safety in the Canadian railway system.

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Circadian Technologies, Inc.