U.S. Department
of Transportation

**Federal Railroad
Administration**

Engineman Stress and Fatigue: Pilot Tests

Office of Research and Development
Washington, D.C. 20590

DOT/FRA/ORD-92/17

June 1992
Final Report

07 - Human Factors

Technical Report Documentation Page

1. Report No. FRA/ORD/92/17	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Engineman Stress and Fatigue: Pilot Study		5. Report Date February 1993
		6. Performing Organization Code
7. Author(s) George I. Kuehn		8. Performing Organization Report No. E06641/E06642
9. Performing Organization Name and Address IIT Research Institute 10 West 35th Street Chicago, IL 60616-3799		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DTFR53-82-C-00254
12. Sponsoring Agency Name and Address Federal Railroad Administration Office of Research and Development 400 Seventh Street, S.W. Washington, DC 20590		13. Type of Report and Period Covered Final Report February 1991 - June 1992
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

In this pilot study, the effects of fatigue on the train handling performance and vigilance of four certified train service locomotive engineers was assessed while they operated the Federal Railroad Administration (FRA), Research and Locomotive Evaluator/Simulator (RALES). Subjects operated on an hourly cycle of 12 work-12 rest-8 work as a "normal" cycle followed by an hourly cycle of 12W-8R-8W the following week as a "fatigue cycle".

Subject activity diaries, scoring of various aspects of train handling, subject exit interviews, and observer's run observation notes were collected. Core body temperature and performance on a fitness for work measure were also recorded.

As a group, the subjects were not found to perform any differently during the second day of the normal (12-12-8) schedule than they had during the second day of the fatigue (12-8-8) schedule. During the course of the experiment, however, subjects were observed to doze or nod off. The subjects similarly reported these instances in exit interviews. Speed limit infractions, failures to blow the horn for crossings, rapid throttle changes and excessive train forces were also observed.

The sleep records of the subjects were plotted and found to be atypical in comparison with those of non-engineer persons. The controlled, low interruption rest periods of the study may have been superior to the rest normally attained by the subjects, thus accounting for the failure to show differences between the two experimental conditions.

The observed deterioration of performance regardless of schedule, coupled with the irregular sleep/work patterns of the subjects suggest continued research which focuses on sleep/work patterns and those performance related variables which were attendant on the decreases in performance in the pilot study.

17. Key Words Fatigue, Stress, Locomotive Engineer, Simulator, Sleep, Hours of Service		18. Distribution Statement Document is available through the National Technical Information Service (NTIS), Springfield, Virginia 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 71	22. Price

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PREFACE

The work described in this report was conducted by IIT Research Institute (IITRI) under authorization of Federal Railroad Administration (FRA) Contract No. DTFR53-82-C-00254, Task Order No. 9. The period of performance was from February 22, 1991 to June 30, 1992. The work was directed at a pilot study of various factors of stress and fatigue in locomotive engineers. The variables of interest were determined by the Volpe National Transportation Systems Center (VNTSC) at the request of the FRA.

The original IITRI Project Manager for this work was Mr. John Granath. The work was concluded, subsequent to Mr. Granath's retirement, by Dr. George I. Kuehn. Mr. Garold R. Thomas was the FRA Contracting Officer's Technical Representative on this project. General consultation and specific assistance in regard to physiological measures and the measurement of fitness for duty were provided by Dr. Donald Sussman and staff of VNTSC. The assistance of all concerned throughout the course of the work is gratefully acknowledged.

Respectfully submitted,

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Approved:

C. E. Radgowski
Director
Transport Technology

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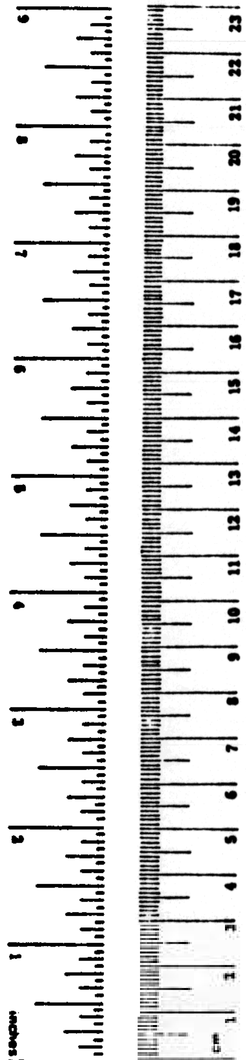
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

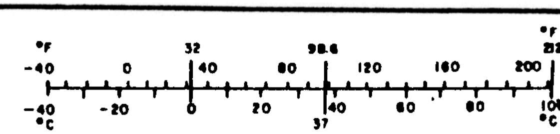
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



ENGINEMAN STRESS AND FATIGUE

1. INTRODUCTION

This Task Order involved the observation of the effects of fatigue on the train handling performance and vigilance of a limited number of locomotive engineers while operating the Federal Railroad Administration (FRA) Research and Locomotive Evaluator/Simulator (RALES). Subjects operated on an hourly cycle of 12 work-12 rest-8 work as a "normal" cycle followed by an hourly cycle of 12W-8R-8W the following week as a "fatigue" cycle.

1.1 THE STUDY

During the months of December, 1991 and January, 1992, four certified train service locomotive engineers were individually oriented to the operation of the RALES FRA Class 1 simulator at the IIT Research Institute (IITRI). The subjects were also given a sleep/work diary to keep.

Approximately one week after the orientation, each subject reported to IITRI, handed in the completed sleep/work diary and commenced to perform repeated simulated runs of approximately 1-1/2 hours duration over a 12 hour period. There were two territories, and these were alternated in the same order for each subject. An observer was present, in the locomotive cab, during each run.

Scoring of various aspects of train handling were collected as well as the observer's run observation notes. Following the 12 hour period, the subject was taken to a nearby place of rest and not disturbed until 10 hours later, when a "crew call" was made to inform the subject to report in 2 hours. Within two hours of the call, the subject returned to the RALES facility and performed the same schedule of runs followed during the previous day. Scoring of train handling, observer notes and an exit interview were collected. The subject was given a new work/sleep diary to keep.

Approximately one week later, the subject returned to repeat the two day sequence with the exception of the rest period being only 8 hours in duration with the "crew call" coming after the 6th hour. All other conditions and data collection remained the same as those used in the first experimental period.

1.2 OVERVIEW OF RESULTS

Subjects were observed to doze off while running during the experiment and were able to report this fact as well as observe that they could have made a serious mistake due to tiredness. They produced performance errors during the study which were potentially hazardous, particularly in regard to signaling for crossings and observation of speed limits.

As a group, the subjects were not found to perform any differently during the second day of the normal (12-12-8) schedule than they were during the second day of the fatigue (12-8-8) schedule. While subjects were more likely to indicate during exit interviews that they were more fatigued at the end of the fatigue schedule, they were more likely to indicate they had dozed off during the normal schedule. Observers tended to corroborate these reports.

There is a possible explanation for the lack of difference between the normal and fatigue schedules. The sleep records of the subjects were plotted and found to be atypical in comparison with those of non-engineer persons. It seems possible that the controlled, low interruption rest periods of the study were, in effect, superior to the rest normally attained by the subjects. This is not to say, however, that the subjects failed to demonstrate dangerous levels of fatigue during the study.

There was no clear deterioration in train handling performance between the first and second days (in either the normal or fatigue schedules). This is not to say, however, that the engineers performed without error. Speed limit infractions, failures to blow the horn for crossings, rapid throttle changes and excessive train forces were evident for each of the subjects. While aggressiveness (heavy applications of throttle and brake) in train handling without a concomitant reduction in elapsed time was evident, this behavior also was not related to schedule or day. There did not seem to be a correspondence between bouts of dozing as noted by observers and runs in which an increased number of errors occurred. It may be that a more time sensitive method of performance evaluation would reveal a relationship between the condition of observed dozing and train handling errors.

Core body temperature was recorded at the request of The Volpe National Transportation Systems Center (VNTSC) for each of the subjects throughout the two experimental periods. Complete temperature data were not recorded for each subject due to body mass of subject, equipment failure, or possible operator error. Those data which were collected provided traces of temperature fluctuations which appeared to agree with subjects' scheduled sleep periods during the study. The data were forwarded to VNTSC for analysis. A fitness for duty test (*Synwork*) was also administered at various periods during the study at the request of VNTSC. The *Synwork* results were reviewed at IITRI and showed progressively increasing total performance scores which would seem indicative of practice effects over

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2. THE SUBJECTS

Four subject engineers were solicited. These engineers had the following experience:

Subject #	Age	Experience
8135	33	3 yrs 6 months
3560	39	2 yrs 6 months
1646	36	13 yrs
9431	37	13 yrs

One of the subjects was female. The subjects were promised confidentiality of results; revealing gender would reveal results. There was not a sufficient number of subjects to allow a determination of differences based on gender.

The subjects attended individual orientation sessions during which the experiment was explained to them, the fitness for duty test practiced (*Synwork*), and an approximately 1 to 2 hour orientation trip taken on the RALES simulator. The subjects read and signed agreement and information forms (Appendix A) at this time.

Despite compensation of $250 per day (for 4 days) plus possible bonus performance incentives (US Series EE Savings Bonds) with a face value of up to $1,500, locating appropriate subjects proved to be a difficult task. At the time of the study, economic conditions had caused railroads whose engineers resided in the Chicago area to maintain limited rosters of engineers. As a consequence, working engineers tended to be frequently called and were thus unavailable or unwilling to "mark off" for the time periods required.

3. THE PROCEDURE

3.1 ORIENTATION

Each subject spent approximately 6 hours in orientation. In addition to the formalities of paper signing and explanation of the purpose and procedures of the study, the subjects practiced *Synwork* and prepared to make the actual train runs required in the experiment. Additionally, the subjects were provided with sleep/work diary forms and instructed in their use over the approximately one week period which would pass prior to their experiment runs.

Synwork is a fitness for duty test requested by the Volpe National Transportation Systems Center. The task was performed on a personal computer and involved four simultaneously presented subtasks. The first subtask consisted of a Memory task (Sternberg) requiring recollection of letters from a previously presented stimulus set. The second subtask was Arithmetic, which required the solution of addition problems with 2 addends. The third subtask was Visual monitoring, which required the resetting of a moving pointer. The fourth subtask was Auditory Monitoring, which required the discrimination of a high tone versus low tones (presented in approximately a 17 high to 100 low tone ratio). The default values of *Synwork* were used with the exception of the auditory tones which were shifted to 2000/1400 Hz in anticipation of the high frequency hearing loss often encountered in experienced locomotive engineers. Subjects were taught the tasks and then allowed to practice for as long as they wished at the beginning and end of the orientation day. A performance incentive of savings bonds of $500, $200, $100 and $50 was offered for the ranked scores obtained during the experiment.

VNTSC also requested the collection of deep body temperatures in the subjects by use of a instrumented "pill" to be swallowed by the subjects. The device was to record body temperature throughout the experimental periods on a 30 second interval. The signals were picked up by an antenna belt and fed to a recorder (Cortemp) worn by the subjects. Negative responses by correspondent engineers to such a device during the study planning period led the investigators to offer a performance bonus consisting of a $1,000 Series EE US Savings Bond to any subject who would agree to wear the device and perform in a professional manner for the duration of the experiment. All 4 subjects accepted the device.

The simulator orientation of the subjects consisted of a discussion and review of the track charts of the two territories to be covered during the study. Train orders and other requirements of the two exercises (Appendix B) were also discussed. Following this, the subjects were introduced to the IITRI simulators and given an opportunity to operate the mixed goods 117 car train selected for the experiment. All of the simulator orientation was conducted by an experienced and certified supervisor of engineers familiar with the equipment and territory both in reality and in simulation.

3.2 THE SUBJECT'S TASK

Each subject was driven to the experiment site for the first day of the study and reported at 0900 hours to the RALES complex. (Transportation was provided throughout the experiment for purposes of schedule maintenance, safety, and control of subject movement). The sleep/work diary was collected and vital signs measured and recorded on a Run Description Form (Appendix C) by a medical specialist. Following this, the Medical Specialist administered the deep body temperature measuring "pill" and attached an antenna and recording device to the subject. These tasks required approximately 15 minutes.

The subject then performed the *Synwork* task for 10 minutes. (The time period was internally controlled by the software.)

The subject then proceeded to perform the two exercises (called "Rochelle" and "Davis Junction") repeatedly for a 12 hour period with two meal breaks and short comfort stops at the end of each run. The duration of the runs varied from 1 hour and 30 minutes to 2 hours depending on the subject's speed and efficiency. The subject was accompanied by one of two experienced observers. The observers kept notes on the Run Description Forms of each run's progress. Additionally, the observers served in the role of both brakeman and dispatcher (in regard to the exercises). The exercises were run in the same sequence for each subject and continued until the 12 hour period was completed. While serving in the role of brakeman, the observers were instructed to call signals if the engineer participated and to converse only if the engineer maintained the discussion.

During the runs, an alertor and an end-of-train device were in operation. In addition to track charts and train orders, the subject had a video display terminal which presented a moving record of the territory and real time train/track data in regard to speed, in-train forces, and braking system status. This "ATCS-like" display was used to level the effects of differences in engineer learning rates in becoming familiar with the two territories used.

The RALES operating crew and observers were rotated throughout the experimental operating period.

Following the 12 hour run, the medical specialist met the subject, assessed and recorded vital signs and checked the temperature recording device. Additionally, the *Synwork* exercise was repeated.

The subject then taken nearby hotel and disturbed until hours had passed At the end of hours rest, Crew Call made to the subject room and instructions giv for reporting hours

The subject then delivered the RALES facility 0900 and the cycl repeated exactly before for period of hours At th end of the hours, the subject was again examined by the medical specialist and the *Synwork* exercise administered Additionally the subject administered exit interview (Appendix C) which requested information about condition and fatigue during the experiment Just prior to returning home, the subject given fresh sleep/work diary Appendix C)

After approximatel week, the sub returned repeat the experiment with the only variations being starting time of 000 hours for the first day and reduction of the rest period from hours The crew cal again made hours prior to the reporting time, but in this the cal 0400 and th reporting time 0600 hours This effectivel reduced the subject sleep to approximately hours

4. DATA COLLECTION PROCEDURES

The RALES simulator allows the continuous collection of virtually every aspect of a chosen train's status as frequently as .5 second intervals. Because of the length of the experimental sessions, and the large amount of data to be recorded, collection was triggered on 3 second intervals. Previous experience has indicated this interval to be sufficient to capture all of an operator's control actions as well as accurately register both steady state and dynamic forces in the train.

The RALES system allows the evaluation of data in terms of flags which are set to capture instances where observed values exceed preset limits. Flagged errors were collected for each run made by each subject. Since the distances for given repetitions of runs varied slightly, an errors per mile figure was calculated for each run by dividing the number of miles into the number of errors for that run. The following performance data were flagged:

Speed Limit Violations: Specific speed limits were set for various locations on each of the two runs and were flagged when exceeded. This was chosen because of its importance under Federal and railroad rules.

Horn Violations: When an engineer failed to blow the horn for a crossing, the event was flagged. This was chosen since crossing accidents are the most frequent FRA defined Accident involving loss of life.

Excessive Draft Force: Excessive draft force is generated when tractive effort, ascending grade, the delay effect in air brake release at the rear of a train, or the retarding effect of track curvature cause a pulling force which stresses the draft gear of the train beyond its limits. Proper train handling requires an avoidance of these conditions whenever possible. While the design limits of the draft equipment are circa 350 to 400 thousand pounds, excessive draft forces were flagged at > 200 thousand pounds for this study. This flagged limit was set as an upper acceptable boundary for the equipment and terrain simulated in the study.

Excessive Buff Force: Excessive buff force is generated when the effects of dynamic braking, locomotive air braking and descending grade apply a compressive force towards the head end of the train. Excessive buff forces can cause derailment of the train, particularly in curved or descending grade territory. The flagged limit for the study was set at -100 thousand pounds. This relatively light limit was chosen for buff, run-out and run-in forces for a number of reasons. The terrain for both territories did not have extreme ascending or descending grades. The train handled by the subjects was a mixed goods train which did imply the possibility of damage to lading at 150 thousand pounds of force. Prior experience with both train and terrain had led to the conclusion that reasonable handling in the specific exercises would rarely produce forces in excess of a threshold of 100 thousand pounds.

Excessive Run-Out Force: There is 6 inches of slack in each standard coupler junction in a train. A freight train of 100 cars (which is not particularly large for a main line freight) has a total of 50 feet of slack. Sudden changes in the forward motion of the train can cause this slack to be suddenly taken up with a force sufficient to cause anything from damage to lading to train separation and derailment. A limit of 100 thousand pounds was set as a flag for the study.

Excessive Run-In Force: Run in forces are similar to run out forces and can cause anything from damaged lading to derailment. The limit for run in was flagged at -100 thousand pounds.

The following five types of errors were flagged in regard to the use of the air brake system. The reason for this emphasis was the importance this system has for the safe control of the train and the serious consequences which can arise from its misuse.

Auxiliary Pressure and Brake Pipe Pressure: These variables can be used to determine inappropriate and dangerous use of the air brake system which can cause an eventual loss of braking effort. The flags were set to trigger at values of < 55 psi.

Cycle Braking: This is another variable which indicates inappropriate use of the air brake system. It is defined as a reduction (use of the air brake) of more than 5 psi that is made when the brakes have been in release for less than 30 seconds. This practice is dangerous and can also lead to loss of braking effort.

Heavy Reduction: This air brake variable is another measure of a potentially dangerous practice (under most conditions). A reduction of the brake pipe pressure by the engineer causes the brakes to be applied. A heavy reduction is dangerous because it limits the potential of the braking system for effort in a subsequent stop. Heavy reduction was defined as a reduction of greater than 15 psi of the brake pipe while the train was moving.

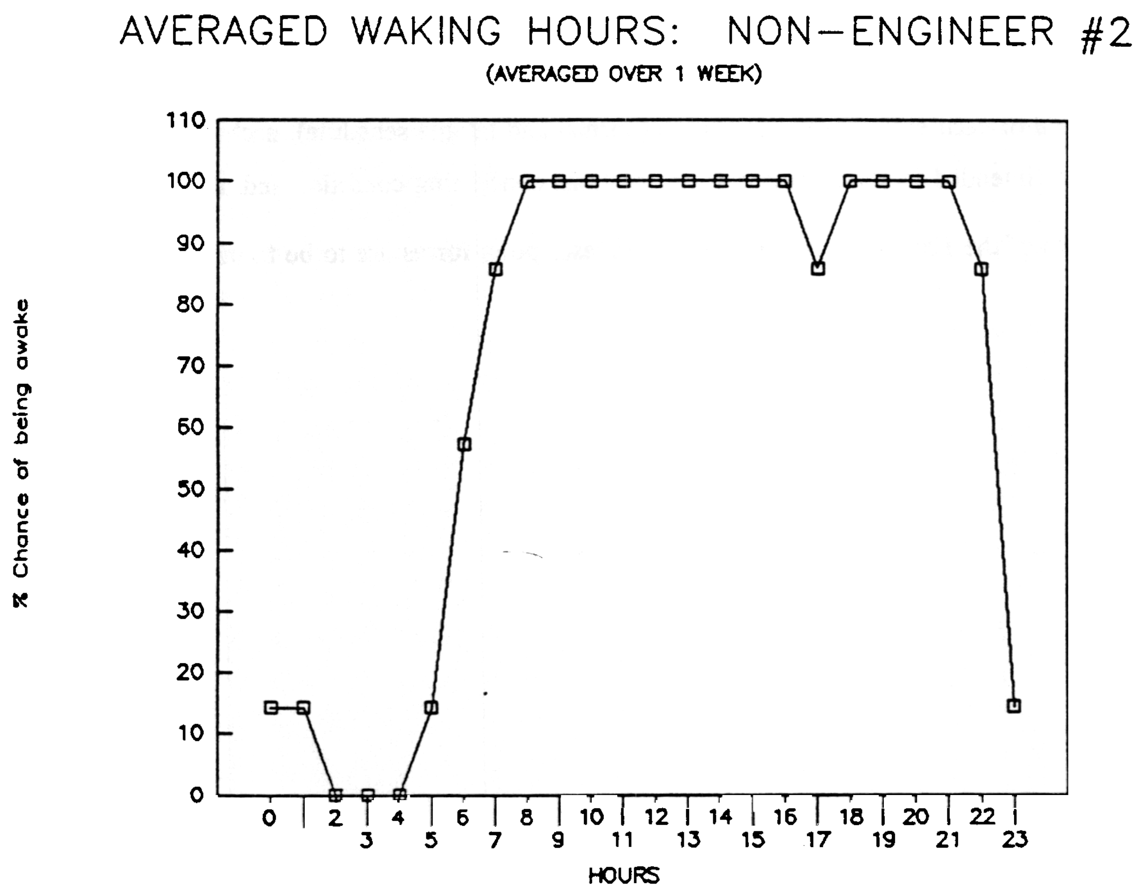
Running Release: A running release of the air brake was defined as the release of a greater than 10 psi brake pipe reduction at a train speed of less than 10 mph. The nature of the air brake system is such that the braking effort cannot be released quickly enough at the rear of the train under these conditions. This practice has the potential to cause excessive in-train forces ranging from damage to train separation and possible derailment.

Throttle Change: Rapid throttle changes can be dangerous in some instances, particularly in situations where the train is "draped" over a hill crest. In the context of the current study, rapid throttle change also served as a possible indicator of vigilance loss similar to the infrequent but large steering corrections noted in fatigue studies in highway vehicles. Rapid throttle change was defined as a change of handle position in less than 3 seconds.

Attack: Another performance measure was developed for the study. The author has decided to name this measure "Attack." The RALES simulator provides a record for each run of the energy distribution in horsepower hours times 10. Energy is added to or removed from the train by a number of factors including the engineer's use of the throttle and braking system. Skill and efficiency in train handling can be measured by how an engineer manages the kinetic and potential energy in the train. The energy put into the train by the engineer (power in the traction motors) was summed with the absolute value of the energy removed through use of the automatic and dynamic brakes. Prior experience on RALES has indicated that aggressive operation of the throttle and braking systems does not necessarily equate to reduced elapsed times!

Elapsed Time: As an additional measure, elapsed time for each run was recorded. In freight service, trains in the United States rarely run on fixed schedules. Instead, trains leave terminals as dictated by situational needs. The objective in freight operation is to finish a run as quickly as possible in a way which is consistent with operating rules, speed limits, and train orders. An engineer accomplishes this goal by operating the train close to but not exceeding speed limits without causing excessive in-train forces. The acceleration of an average freight train is typically on the order of 9 to 12 miles per hour per mile; the deceleration due to braking would typically be twice the acceleration value. As a consequence, operating safely at or near speed limits requires considerable strategic planning in the anticipation of grade changes and train orders requiring speed changes.

Sleep Patterns: The author chose to characterize the sleep patterns in the engineer subjects' sleep/work diaries by assigning a value of 100 to an hour in which a subject was awake and 0 to an hour in which the subject slept in any given day. Then, these assigned values were averaged for each hour over a diary period to give an index of the chances of a subject being awake at any hour. Additionally, the mean and standard deviation were calculated for all the hours. A graph for a typical day worker is shown on the following page. For a person with predictable sleep habits, a given hour is likely to have extreme values...we typically are asleep (value of 0) or awake (value of 100) at specific hours in the day.



Example of Sleep Record Graph

Only late hours or daytime naps on weekends tend to move values away from 0 or 100. This analysis seemed to be particularly useful in describing sleep patterns.

Anecdotal Information: Throughout each run, the in-cab observers maintained a Run Description form on which to record any information which might provide insight to the subject's condition and attentiveness.

At the end of each experimental condition (normal and fatigue schedule), each subject was given an Exit Interview intended to solicit personal observations concerning condition and attentiveness.

Examples of the Exit Interview and the Run Description forms are to be found in Appendix C.

ESULTS

AL NG ASLEEP

Both observers Run Description notes and subj Exit Interviews indicated dozing and near-sleep states (marked inattention to environmental stimuli) The observers familiar with the concept of micro sleep ince the observers rotated regularly in the locomotive cab they "fresh. Additionally the observ experienced train operation and thus sensitive ituations in which boredom ikel or hen igh attention required Both observers had experience in operating over the territories used in the study The ertor functional during all The alertor ashed upon occasion but never sounded

As discussed earlier complete core temperature data not recorded for each subject due to body mass equipment failure, possible operator error The data which collected forwarded to VNTSC for analysis but did appear show temperature fluctuations which agreed with periods of dozing performance deterioration recorded by subjects observers

<u>The Normal Schedule:</u> The observers noted signs of fatigue and possibl episodes of dozing in **all** subjects during the Normal Schedul One exit interview inadvertentl not administered subj the end of the Normal Schedule Of the three subjects interviewed only claimed to have not "blanked out doze(d) off" during the Normal Schedule (Item #4 Ex Interview). Interestingl enough **all** three subjects responded that they could have made serious mistake because (they) were tired, but only two times (Item 2)

On open ended item (# 1), subject volunteered that would have been harder to stay wake in real ife because there would have been fewer breaks Responses made this item indicating that would have been easier to stay awake in the real world due

Weather changes

Lack of breaks eading to (sic) higher concentration

Calls to dispatcher/conversation with crew

All subjects ind cated they were either somewhat fresh ittl tired (Item #3) at the end of the Normal Schedul

Two of the three subjects indicated that it was easier to stay awake during the Davis Junction runs. The experienced supervisor of engineers at IITRI who designed the exercises has indicated that the Davis Junction run is equivalent to the Rochelle exercise in the sense of terrain, but has more crossings and speed changes. Two of the three subjects indicated that they found it was harder to stay awake on Rochelle. Comparatively, however, error rates were no higher on Davis Junction than Rochelle (Rochelle mean error per mile = .534; Davis Junction e/mi = .567).

The concept of operating challenge making it easier to stay awake seemed to be supported by subject choices to a number of Exit Interview items. Train handling tasks requiring little attention such as operating over level terrain or heavy ascending grades were seen as conducive to sleep while more challenging terrain such as descending grades and hogbacks were seen as conducive to alertness.

The Fatigue Schedule: The observers noted signs of fatigue and possible episodes of dozing in only 2 of the 4 subjects during the Fatigue Schedule. Of the four subjects interviewed, only one claimed to have not "blanked out" or "doze(d) off" during the Fatigue Schedule (Item #4, Exit Interview) and the Observers agreed with this report. Only 1 of the 4 subjects responded that s/he "could have made a serious mistake (because of tiredness), but only one or two times" (Item #12).

On an open ended item (#11), one subject volunteered responses concerning staying awake similar to those offered on the Normal Schedule. In regard to real life factors making it harder to stay awake, the subjects offered new responses:

- No meals
- Sitting in sidings
- The "sun factor" in the morning hours

Three of the subjects indicated they were moderately tired and one subject "a little tired" (Item #3) at the end of the Fatigue Schedule.

Three of the 4 subjects indicated that it was easier to stay awake during the Davis Junction runs. This finding agrees with the Normal Schedule interviews. Surprisingly, 2 of the 4 subjects also indicated that they found it was equally hard to stay awake on the two exercises.

The concept of operating challenge making it easier to stay awake was also supported by subject choices of Exit Interview items following the Fatigue Schedule. There was high consensus that starting and accelerating the train were more conducive to sleep while slowing and stopping were conducive to alertness.

Subject By Subject Report: Subject S8135 did not show signs of inattention or nodding during the experiment except for a slow reaction at one point during the afternoon of the first day on the normal schedule. All other subjects were described as being inattentive or nodding at least one time on each day of both the normal and fatigue schedules. In all but one case, the nodding or inattentive events took place during times in which the subject characteristically would have been awake (according to the sleep diary data).

In the one case alluded to above, subject S9431 was described by observers as having five incidents of nodding or inattentive behavior on the morning of the second day of the fatigue schedule. Four of the five events took place in a time period which coincided with time during which the subject was only 25 to 45% likely to be awake. In the exit interview, the subject did report difficulty staying awake during this period. Unexpectedly, the error per mile rate for this subject during this run was very low compared to the subject's own record. The error per mile rate for this subject's particular run was only 50% of the highest error rate posted by the subject for this run. The implication of this finding will be discussed in the results section.

The subject sleep histories are unusual when compared to those of non-locomotive engineers. The histories are presented on the page which follows. The histories of the investigator and a colleague are also presented for comparison.

Sleep Histories: All of the sleep diary data for each subject was organized in two ways; first as a sleep record graph and second, as a sleep chart which presents sleep/work/other designations by hour and date.

The sleep record graphs were intended, as discussed previously, to represent the regularity of sleep/awake cycles over time for the subjects. To this end, each graph represents a 24 hour period with each hour set to reflect the average state for a subject at that hour over all that subject's diary data. Each graph covers diary information through the beginning of the fatigue schedule part of the experiment. One week histories of two day-working non-engineers are shown for comparative purposes.

The shape of the engineers' graphs indicates a sleep/awake pattern which can be characterized as "irregular" in the sense that there are shorter periods of sleep coupled with an uncertainty that sleep or work will happen at a given hour. All of the subjects have irregular patterns in which there are literally no hours in a day in which sleep may be expected with absolute certainty. Subjects 9431 and 8135 had a limited certainty that they would be awake at any given hour. Subject 3560 had no time in 24 hours, averaged over an approximately two week period, in which being asleep or awake could be expected with certainty.

The study began with the intent to obtain two subjects who worked during the day and two who worked at night. The reality of work for potential subject engineers available at the time of the study did not avail itself to this binary designation. Consistent with other investigations of engineer work schedules, the subjects in the current study had irregular sleep/awake patterns.

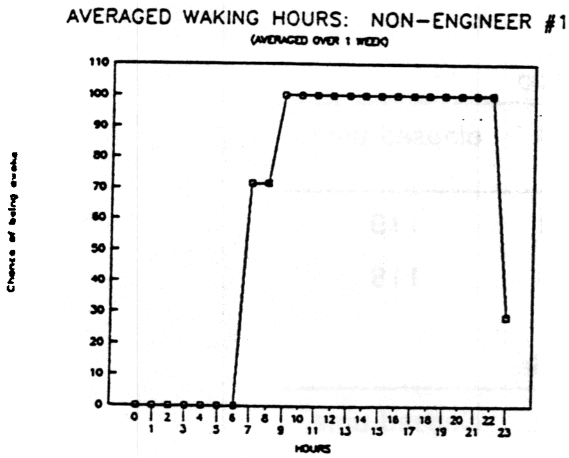
As discussed earlier, the mean and standard deviation of the averaged sleep hours seemed to be a useful index of sleep pattern. An irregular sleep pattern has a small standard deviation since there would be few hours in a 24 hour period during which one would predictably be awake (score of 100) or asleep (score of 0). Similarly, reduced sleep produces a high mean for an individual, since there is increased likelihood that an individual would be awake at any given hour. As can be seen below, the subject engineers did not differ appreciably from the non-engineers in mean sleep but they differed markedly in terms of standard deviation.

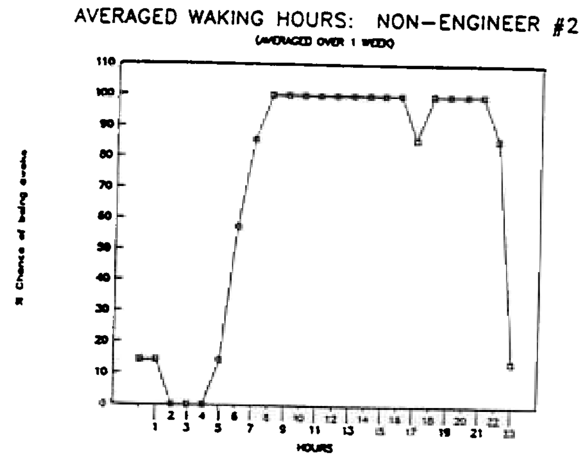
AVERAGED SLEEP HOURS

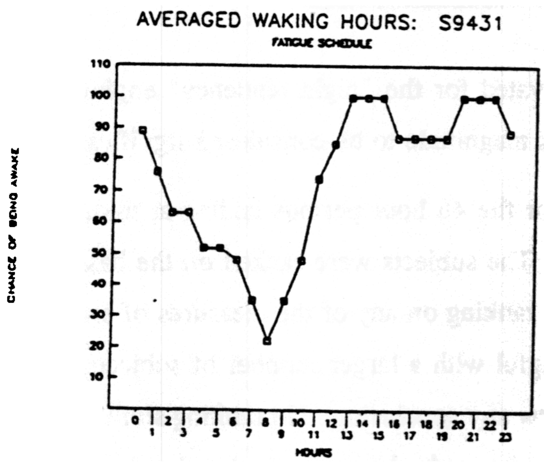
	MEAN	STD. DEV.
Non-Engineer #1	65.5	44.8
Non-Engineer #2	69.6	40.7
8135	66.0	
1646	72.5	
3560	65.8	25.0
9431	74.2	23.8

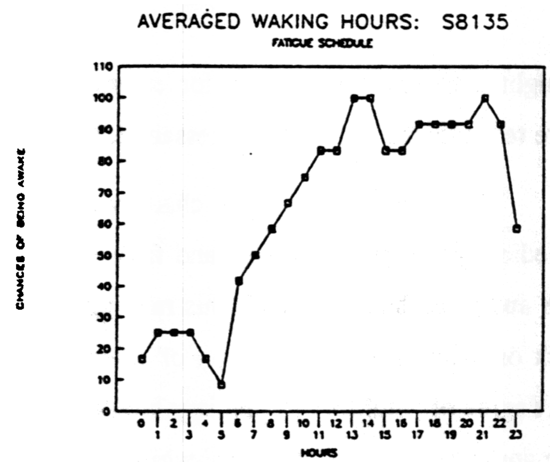
An attempt was made to compare error rates with sleep patterns by overlaying normalized error per mile scores (at the time of run end for each run) on the sleep pattern graphs. No clear relationship was found. Error rates seemed as likely to be high at an hour of average wakefulness as they were to be low at the same time.

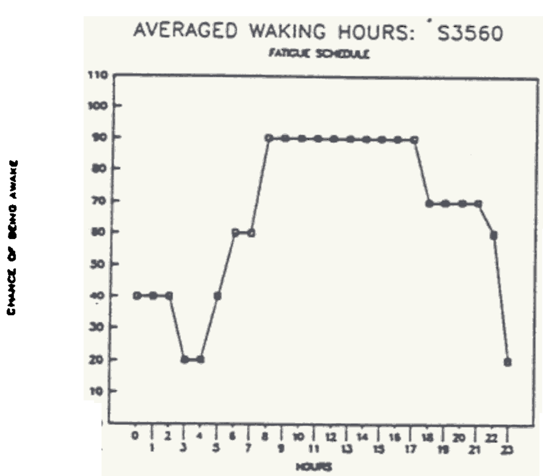
In a further attempt to study possible effects of circadian shift, the hour by hour sleep charts of the subjects (Appendix E) were studied. It was noted that two subjects (8135 and 9431) had a somewhat greater tendency to work at night and then sleep late, to about 10 AM. This tendency, it should be noted, was not an absolute guarantee of sleep during the morning hours or of work during night hours. The error per mile, attack and elapsed time averaged figures for subjects grouped on the basis of this distinction are shown below.

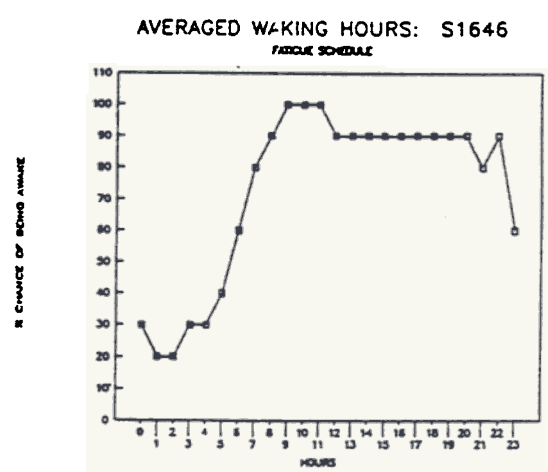












Sleep Record Graphs:
Chances of Being Awake on the Basis of Diary Averages

Normal Schedule

work tendency	error	attack	elapsed time
	57	1173	119
	.47	1150	118

Fatigue Schedule

work tendency	error	attack	elapsed time
night	.57	1127	116
day	.50	1177	117

A slight tendency can be seen for errors per mile to be elevated for the "night tendency" engineers. More test subjects would be necessary for a difference of this magnitude to be considered significant.

The hour by hour sleep charts were also reviewed for the 48 hour periods ending at midnight immediately before the normal and fatigue schedules began. The subjects were ranked on the basis of work and sleep hours to see if this ranking was similar to the ranking on any of the measures of errors, attack or elapsed time. This sort of analysis is more meaningful with a larger number of subjects. A high degree of similarity in rankings would be necessary to draw any conclusion. No ranking similarities were apparent. One of the worthwhile observations which can be made, however, is that the sleep and work patterns were extremely varied.

5.2 TRAIN HANDLING AND FATIGUE

There was no significant difference in the performance of the subjects as a group on the normal and the fatigue schedules. Averaged figures, comparing the second days, are presented below. The Attack figures are in units of horsepower per hour times 10 and are a measure of the degree to which the engineer adds and subtracts energy from the train with the controls. The Elapsed Time is stated in minutes required to complete a run.

PERFORMANCE ON NORMAL AND FATIGUE SCHEDULES

	Error/Mile	Attack	Elapsed Time	No. of Runs
Rochelle District:				
Day 2 Normal Schedule	0.46	1055.43	111.71	8
Day 2 Fatigue Schedule	0.40	1084.75	110.75	8
Davis Junction District:				
Day 2 Normal Schedule	0.60	1255.75	125.00	4
Day 2 Fatigue Schedule	0.66	1219.50	122.75	4

In addition to the sleep chart investigation covering the 48 hour periods before normal and fatigue schedules, another review of averaged figures of sleep, work and personal time over the same 48 hour period was made to determine if there were any variations in these patterns which might account for the lack of difference between the schedules.

Average Hours of Sleep, Work and Personal Time
(All Subjects Combined)

Schedule	Sleep	Work	Personal
Normal	14.25	15.5	18.25
Fatigue	12.50	11.5	24.00

The sleep averages are opposite those which would have been expected to decrease performance on the normal schedule or increase performance on the fatigue schedule. The work schedules could conceivably have influenced the result, but a close examination on a subject by subject basis does not show a tendency for the work hours to be grouped immediately before the experimental period began on either schedule. Additionally, the work figures on the normal schedule are inflated by office work (in addition to locomotive operating time) performed by one subject who was in preparation for transfer to a supervisory post.

Since there were no differences between normal and fatigue schedules, the question arose as to whether the schedules themselves were significantly different from the daily experience of the subjects. To this end, the Sleep Charts were again reviewed. The subjects had, on average, 6-7 hours of sleep, 6-7 1/2 hours of work and 9-12 hours of personal time in a 24 hour "real world" period. Further, the subject by subject Sleep Chart review revealed that subjects rarely failed to have at least 6 hours of uninterrupted sleep in their daily lives. The exceptions were two subjects who each had 2 (non-continuous) days in which they failed to have at least 6 continuous hours of sleep (and these not contiguous to the experimental sessions). In terms of uninterrupted sleep, therefore, the experimental periods did not differ from each other in a way that made them distinctly different from the daily experiences of the subjects. Where the difference in sleep did exist was that the subjects were able to expect the actual time at which they would be able to sleep during the experiment with a higher level of certainty than what they experienced in daily life. The experimental schedules differed from everyday life in the sense that less personal time was available to the subjects during the study than they would experience in everyday life.

One of the distinguishing characteristics of the subjects was a marked difference in terms of years of experience. Half of the subjects had less than 4 years of experience and the remaining half had greater than 10 years. Interestingly, there was no difference in age of the subjects; they ranged from 33 to 39 years, with no clear distinction related to years of experience. The errors per mile, attack and elapsed time figures are shown below:

Performance Relative to Years of Experience

Schedule	Experience	Subject	Error/Mi.	Attack	El/Time
Normal	< 5 yrs	8135	.58	1072	119
		3560	.27	1134	117
		MEAN	**.42**	**1103**	**118**
Normal	> 10 yrs	9431	.56	1275	119
		1646	.66	1166	118
		MEAN	**.61**	**1220**	**118**
Fatigue	< 5 yrs	8135	.74	1061	117
		3560	.23	1141	119
		MEAN	**.49**	**1101**	**118**
Fatigue	> 10 yrs	9431	.40	1194	116
		1646	.77	1213	116
		MEAN	**.59**	**1203**	**116**

With the exception of a 2 minute shorter elapsed time under fatigue schedule conditions, the more experienced subjects seemed to not perform as well as the less experienced subjects. This conclusion should be considered tentative, however, since there was considerable variation in the error per mile figures within the experience grouping.

No differences existed between normal and fatigue schedules. The engineer subjects did not show a significant increase in their rate of errors per mile on the second day of running of both schedules. Twelve hours of running on the first day followed by either 8 or 12 hours of rest and concluding with 8 hours of running on the second day did not produce an increase in errors on the last day.

Day one versus day two results:

	Error/Mile	Attack	Elapsed Time	No. of Runs
Rochelle District:				
Day 1 Normal Schedule	0.42	1108.50	116.00	8
Day 2 Normal Schedule	0.46	1055.43	111.71	7
Day 1 Fatigue Schedule	0.37	1101.45	108.45	11
Day 2 Fatigue Schedule	0.40	1084.75	110.75	6
Davis Junction District:				
Day 1 Normal Schedule	0.67	1193.63	122.13	8
Day 2 Normal Schedule	0.60	1255.75	125.00	4
Day 1 Fatigue Schedule	0.64	1236.25	122.00	8
Day 2 Fatigue Schedule	0.66	1219.50	122.75	4

Since there were differences in engineer performance between first days and second days for each of the runs, a statistical test called the "t test" was used to determine the extent to which differences between days could have happened by chance alone. In the case of the current study, it was decided that any difference which could have occurred by chance 5 times in 100 or less would be considered significant. The selection of the .05 significance level is arbitrary, but consistent with research of this kind.

Two constraints which apply to the t test are number of samples (degrees of freedom) and expected direction of difference (one vs. two tailed). There were sufficient degrees of freedom to calculate the difference between pairs of means (t test) for each of the performance criteria. No test had a significant result at or beyond a .05 (2-tailed) level.

6. DISCUSSION OF RESULTS

No differences were found in subject performance between the "normal" and the "fatigue" schedules. One possible reason for the failure to find differences was that both the normal and the fatigue schedules of the study inadvertently provided the subjects with an assured time at which they could expect to sleep. The sleep/work diaries for the subjects indicated a history of adequate sleep in terms of hours, but irregular patterns for when that sleep would occur. Another point which needs to be made is that the "normal" schedule of the study did not necessarily describe an optimal working condition. Twelve hours of work followed by 12 hours of rest resulted in a deterioration in train handling on the following day.

As indicated earlier, the subjects seemed to have incidents of nodding or inattention without regard to schedule or time of day. Subject S9431 did show an increase in observed incidents of nodding or inattention during a period in which sleep would normally have been more likely, but posted a relatively high performance rate for the particular run in which the events took place. One plausible explanation is that engineers do have disrupted sleep patterns (see sleep histories section) which increase the chances of decreased attention during periods in which relatively low levels of operational performance are required.

The subjects indicated, and the observers noted a marked tendency to doze in those instances where few control actions were required of the engineers. Had unanticipated events such as signal changes a short distance from the head end, torpedoes, locomotive malfunctions or the like taken place during periods of low control demands, the error rates might have reflected a higher level. A reading of FRA accident reports involving sleep often reveal situations which might be characterized as low control demand periods. While safe train handling of heavy freights takes considerable skill, the task does differ from highway vehicle driving in that there are periods in which the task does not include a motor component to prompt attentiveness or threaten immediate disastrous consequences arising from inattention to control.

There is further support for the "low demand" explanation: The Davis Junction run did not differ substantially in terms of terrain from the Rochelle run; it did differ, however, in terms of a greater number of slow orders and crossings. Subject engineers generally reported that it was easier to remain awake on the Davis Junction run, yet the engineers' error rates per mile for that run were often equal to or higher than the rates for Rochelle. A conclusion could be drawn that the subjects knew if they were dozing off, but were not necessarily aware of the effect fatigue was having on their mile by mile performance. Fatigue induced error and sleep deprivation induced accidents may, in fact, not be polar points on a single continuum. Since the train handling deterioration exhibited by the subjects was not trivial, it may be necessary to think of fatigue and sleep deprivation (or circadian shift) in distinctly separate ways.

As indicated earlier, the sleep patterns of the engineers were markedly different from that of non-engineers. It may be that the enforced rest regimen of the study with a comfortable room away from home at a predictable time where no other engineers or rail crew members were nearby constituted a rest period superior to that attainable in "real life." Had the sleep been more disrupted, or the schedule of work more irregular (such as an extra-board engineer's experience of 6 hours of work, 6 hours of rest, 6 hours of work), the results might have been more extreme. Two of the engineers did informally comment that they felt better on the second day of a run than the first, even when they were on the "fatigue" schedule of an 8 hour rest period. Real world engineers often do not know when they will be called and cannot, as a consequence, make as much of rest periods as the subjects of the current study were able to do.

The subjects did make a number of comments about the locomotive cab environment. The study did not use noise or ambient temperature levels considered by engineers to be fatiguing. Additionally, the study did not take place during a period of time in which both subject engineers and virtually all correspondent engineers have indicated as a particularly difficult time, i.e., just at dawn. It does remain to be seen if this time is relative to time at a particular location on the planet's surface, or an actual characteristic change in the level of ambient light. In the current study, the engineer subjects did not run at the daybreak period but did tend to show elevated error per mile rates when they undertook runs during the period between 0900 and 1000 hours which has also been characterized as a period of drowsiness.

Given the results of other research in the area of fatigue and sleep, one suspects no clear standard exists for an indicator of sleep deprivation or fatigue which would apply equally to all individuals. What may be hoped for, however, is the definition of a borderline of conditions past which a significant number of individuals become dangerously impaired. The subjects of the current study were willing to admit in the exit interview that they had either dozed or could easily have caused an accident due to tiredness at some point during the experiment.

IMPLICATIONS FOR FURTHER RESEARCH

7. WORK SCHEDULES

The subjects of the study were not apparently fatigued by 12w/12r/8w and 12w/8r/8w patterns, but may not have been sleep deprived or 'circadian shifted. While there may not be exact which applies equally to all locomotive engineers, more could be done in subsequent study explore possible imits extensivel

A. Unanticipated Crew Calls: Perhaps the best would be call extra board engineers who thought they were going to regular work but instead ran on the simulator Our experience in attempting to find subjects indicates, however that would be difficult to meet these conditions A useful alternative would be to let subjects know exactl when they would be called, but rather randomly assign schedules to subjects which were consistent with hours of service rules but not known in advance by the subject.

B. Working Times: The unanticipated calls discussed in A. (above) should fall in such way as to cause the subjects to take their simulator during periods believed to be particularly difficult such as at daybreak or following an unexpected early rising time.

C Working Environment: RALES allows manipulation of temperature and ambient sound levels much more severe (and realistic) than those employed in the current study These factors would be easy to employ

D Lunch Breaks, Comfort Stops: In the current study and largely outcome of the operation pattern of the RALES installation, it easy to provide lunch breaks and frequent stops for personal relief Neither of these events are common under many labor agreements It is more common than not for the engineer to eat self-prov lunch in the cab and seek personal relief at intervals less convenient than those provided in the current study Any subsequent study would be conducted the upgraded RALES facility which will offer rapid turn-around and nearly continuous operation which more closel mimics real world

7.2 PERFORMANCE MEASURES

Performance measurement improvements can be made over the procedures used in the current study.

A. Segmented Scoring: The new conversion of RALES allows for much easier application of the IITRI ScoreBoard™ system of segmented scoring. This scoring is situationally sensitive, allowing a study of specific train handling tasks under specific conditions (rather than to global scoring criteria). This approach would allow a determination of the ways in which the fatigue noted in the current study causes deterioration in discrete train handling skills.

B. Performance Bonuses: None of the performance bonuses used in the current study were attached to the actual proficiency of the engineers in handling their trains. The RALES scoring system easily allows for a reward/penalty program based on elapsed time for a run versus speed limits and acceptable in-train forces. We now have a good collection of data for the runs used in the current study and can easily arrive at appropriate performance standards for future work.

C. Use of Advance Display: A graphic train information display was provided to the subjects in the current study in an attempt to equalize the effects of route-learning on performance. The observers noted heavy dependence by the subjects on this display throughout the study and a possible mesmerizing effect. In future experiments, it would seem advisable to allow the subjects one familiarization run over the territories with the display during orientation, and then have the experimental runs made with either the traditional printed track profile only, or with the moving graphic display of the profile only.

D. Unanticipated Events: Because of the heavy implication in the current study of dozing relative to low control frequency periods, it would seem fruitful to include unanticipated events such as sudden signal changes, torpedoes and emergency applications (in train separations). These things might be undertaken on a limited basis during low control rate periods for at least some subjects to study the possibility of impaired performance.

Finally, a larger number of subjects would be needed to prevent any meaningful findings to be subject to claims of bias rising from individual differences in the subjects rather than from the experimental conditions themselves.

7.3 RELATED RESEARCH

It would seem advisable to include a review of related research in the selection of work/sleep schedules in the design of a future study. To the extent that FRA accident reports involving suspected falling asleep are available, some attempt should be made to recreate work/sleep patterns which were associated with these actual accidents. The work calling and sleep patterns would need to be unanticipated by the subjects in order to be effective.

In conclusion, time and circumstances caused the conscientious participant engineers of the current study to occasionally produce errors which would easily have contributed to serious accidents in the real world. Further research built on the observations of the current study seems justified. There may well be no set of absolutes which would contribute to a set of rules that guaranteed engineers would never have sleep or fatigue related accidents. Alternatively, it does seem possible to develop a safety-enhancing set of guidelines for personal conduct and crew calling practices based on performance evidence gathered from the kind of study the current investigation suggests.

APPENDIX A

This appendix contains the initial Subject Information and Subject Agreement forms used in the study.

SUBJECT INFORMATION FORM

This form explains how you will be compensated for your participation in the study. It also advises you about transportation, lodging and meals during the study. This form also requests limited personal information needed for the study and for tax reporting purposes. Aside from tax reporting, the information you give will be completely confidential.

Compensation: You will be paid $250 for each of the 5 days you spend at IITRI (this includes your orientation day). If you are physically able to take the temperature sensing "pills" as described in the Consent Form, and volunteer to do so, you will receive an additional bonus consisting of a $1,000 Series EE United States Savings Bond. Additionally, bonus incentives in the form of Series EE Bonds will be awarded on a contest basis for total score points achieved during the study on the synthetic work exercises (as described in the Consent Form). The synthetic work exercise prizes will be: 1st place = $500 Series EE Bond, 2nd place = $200 Series EE Bond, 3rd place = $100 Series EE Bond, last place = $50 Series EE Bond. There are 4 subjects and 4 bonds will be awarded. In the event of a tie, the best orientation training score in synthetic work will determine the prize order.

Due to the nature of the limited services you will be performing as part of the research project, it has been determined that you are an "independent contractor" rather than an employee of IIT Research Institute (IITRI). Due to your status as an independent contractor IITRI will not withhold any taxes from the compensation which you receive; however, as is required, IITRI will report the cash compensation and the fair market value of the incentive or non-cash compensation to the Internal Revenue Service on form 1099-Misc. You will receive a copy of 1099-Misc for tax reporting purposes shortly after the year-end in which you receive the compensation.

Lodging, transportation, and meals will be provided by IITRI and constitute a part of the experiment. These will not, therefore, be considered a form of compensation.

Lodging: During the course of the study (as described in the Consent Form), you will be taken for rest to the Richmont Hotel, where a room has been reserved for you. You are required to use this lodging; IITRI will pay your charges excluding any type of room service or phone calls not made to IITRI.

Transportation: In addition to transportation during the experiment, IITRI will provide transportation to and from any point within 50 miles of 10 West 35th Street, Chicago at the beginning and end of each of the two experimental periods described in the Consent Form. Because of the need to assure your safety during periods of fatigue caused by the experiment, use of this transportation before, during and after the experimental periods is required.

Meals: Beginning with a mid-day meal on the first day of each of the experimental periods and ending with lunch on the last day of each experimental period, IITRI will provide or pay for your meals during the course of the experiment. The time period for meals during a simulated run will be limited to 30 minutes.

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Requested Information: In addition to the form FO-117, which is attached, please answer the following questions:

How many years have you spent in engine service?________________

How old are you?__________________

What is your gender (M/F)?

The above information is considered confidential. All of your performance during the study will be identified by a randomly assigned code number. Your performance as an individual will not be reported to your employer.

Please sign your name and fill in the date below. If you have any questions about the information on this form, or the requirements of the experiment, your questions will be answered by **George Kuehn** or his designate.

___________________________________/___________________

(name) (date)

IIT RESEARCH INSTITUTE CONSENT FORM

LOCOMOTIVE ENGINEER SLEEP DEPRIVATION STUDIES

I, ______________________________, consent to be a subject of the research program described below.

1. The purpose of this experiment is to determine how well changes in an engineer's train handling performance can be measured as a function of sleep loss, disruption and circadian desynchronosis (day/night schedule shift). The experiment will be conducted on the locomotive/train simulators at the IIT Research Institute (IITRI).

   I have been selected for this study because I am a normal, healthy, experienced locomotive engineer. Specifically, I do not have or suspect that I have any stomach, digestive, or intestinal problems.

2. I understand that I will be asked to report to IITRI at a specified time to take, as engineman, a simulated heavy freight train on a twelve-hour run. An IITRI observer will accompany me (role-playing "conductor") during the run.

   At the completion of the run, I will go to a designated rest facility for a period of personal activity and rest. I will be accompanied by an IITRI observer.

   After a rest period, I will receive a simulated crew call to report within two hours to IITRI to take a similar heavy freight simulated train on a run of eight hours over the same territory as the earlier run. I will be accompanied by an IITRI observer.

3. During the eight-hour run, I will be required to wear an electronic device to measure. The device is a type worn by NASA astronauts and by persons participating as subjects in other US Department of Transportation human factors scientific studies.

   My deep body temperature will be measured by swallowing a transmitter in the form of an oval shaped "pill" approximately 5/8" x 1/4" in size. The pill will pass normally through my body and be excreted in my stool. The pill is expendable and will not be recovered. I understand that ingestion of the pill is contraindicated in (should not be taken by) persons with problems as described below:

   Obstructive disease of the gastrointestinal tract including (but not limited to) diverticulosis and inflammatory bowel disease. (This means you shouldn't take the temperature pill if you might have anything wrong that would block up your digestive system.)

A history of disorders or impairment of the gag reflex. (This means you shouldn't take the temperature pill if you have any difficulty swallowing.)

Previous gastrointestinal surgery. (This means you shouldn't take the pill if you ever had an operation on your esophagus, stomach or intestines.)

Any hypomotility disorders of the gastrointestinal tract. (If you have problems with constipation, you shouldn't take the pill.)

During the experiment, I will wear an antennae "belt" around my body which is attached to a receiver/computer that will automatically record my internal body temperature. The equipment attached to my body will meet medical standards for safety as reviewed by the IITRI Human Subjects Committee. I understand that my freedom to stand or move about during the experimental period may be restricted due to the equipment attached to my body.

I understand that I should not undergo Nuclear Magnetic Resonance (NMR) scanning during the period of time that the deep body temperature "pill" is within my body.

4. I understand that as a participant in this study I will be deprived of sleep and that as a result, my physical and/or mental abilities may be temporarily affected. I understand that I should exercise caution in my activities during and after the experiment until I am able to resume my normal sleeping habits.

5. I understand that I may contact any of the following individuals with any questions that I may have about this study or my participation in it as a research subject:

Name: George Kuehn
Title: Principal Investigator

Organization: IITRI Transportation Technology Department

Telephone No: 312-567-4148

6. I understand that any questions I have regarding this research or my rights as a volunteer will be fully answered by _George Kuehn_ or his/her designate. Further, I understand that I am free to withdraw my participation in the project at any time without penalty.

7. I understand that, in the unlikely event of a physical injury, medical emergency treatment will be provided. I also understand that neither _George Kuehn_ nor IITRI will be financially responsible for injuries not due to the negligence of _George Kuehn_ or IITRI which may be sustained by me while, or as a result of, participating as a subject in this research program.

8. I understand that I am a volunteer participant in this study and will receive compensation in money but only for the time I am required to spend "on duty" as a locomotive engineer.

9. I understand that I will be given an identifying code when entering the study and that all reasonable efforts will be made to keep my records and information confidential. I understand that the U.S. Department of Transportation will inspect the study records of this experiment.

I have read and understand the various aspects of my participation in this study, all of my questions have been answered, and I voluntarily agree to participate.

Name:______________________________ Name:______________________________
Subject (Print) Witness (Print)

Signature:_________________________ Signature:_________________________

Date:______________________________ Date:______________________________

Consent Form; page 3 of 3
for subjects using temperature pill

APPENDIX B

This appendix contains the exercise instructions used for the two territories (scenarios) run repeatedly in fixed order during the study. These territories were "Rochelle" and "Davis Junction."

RALES SIMULATION EXERCISE:

Stress and Fatigue Study

Rochelle to Savanna

(Standing start at MP 82; Max track speed 50 mph)

1. Accelerate to 35 mph and maintain until entire train is over C & NW crossing.

2. Accelerate to track speed

3. Note flashing yellow signal at MP 89.25

4. Take siding at CHANA MP 92. Limit 25 mph for turnout and through siding. Exit siding not exceeding 25 mph.

5. 45 mph from MP 95.75 (curve) to mp 102.25

6. Complete run complying with signal indications. Stop short of signal at MP 142.3.

RALES SIMULATION EXERCISE:

Stress and Fatigue Study

Davis Junction to Bensonville

(Standing start at MP 80+; max track speed 50 mph)

1. Accelerate to track speed; must reach at least 39 mph at MP 79.
2. Stop for Red MoW sign at MP 75
3. Must request authority to proceed.
4. Do not exceed 20 mph by MP 72 with head end.
5. Stop at MP 59, request permission to proceed from dispatcher.
6. Reduce speed to 25 mph through turn out at MP 44.5 until entire train is through.
7. Reduce speed to 40 mph for turnouts over bridge at MP 35
8. Complete run complying with signal indications. Stop at signal at MP 15.8

APPENDIX C

This appendix contains the Run Description Form, the Exit Interview Form and the Sleep/Work Diary Form.

*Run Description Form**

This form is to be used only for subject#________________________

This subject HAS / HAS NOT volunteered to take the temperature pill.

Date:_____________________ Run on [ ]*TS-2* [ ]*RALES*

NOTE: In case of medical emergency call 4115 or 4116.

+++

MEDICAL SPECIALIST:
(note additional entry at end of form)

Subject's blood pressure at start:________________

Subject's pulse rate at start:__________________

Subject's general condition:____________________________________

Phone were you may be reached today:________________

Signature:____________________________________

+++

EXERCISE NAME:____________________ TIME STARTED:_____________(24 hr.)

TIME ENDED:_____________(24 hr.) YOUR NAME:____________________________

Make notes below to indicate anything unusual that happened including the subject's coffee consumption and "nodding off." Please note the time at which the event happened.

EXERCISE NAME:____________________ TIME STARTED:_____________(24 hr.)

TIME ENDED:_____________(24 hr.) YOUR NAME:____________________________

Make notes below to indicate anything unusual that happened including the subject's coffee consumption and "nodding off." Please note the time at which the event happened.

EXERCISE NAME:________________________ TIME STARTED:____________(24 hr.)

TIME ENDED:_______________(24 hr.) YOUR NAME:________________________

Make notes below to indicate anything unusual that happened including the subject's coffee consumption and "nodding off." Please note the time at which the event happened.

EXERCISE NAME:________________________ TIME STARTED:____________(24 hr.)

TIME ENDED:_______________(24 hr.) YOUR NAME:________________________

Make notes below to indicate anything unusual that happened including the subject's coffee consumption and "nodding off." Please note the time at which the event happened.

EXERCISE NAME:________________________ TIME STARTED:____________(24 hr.)

TIME ENDED:_______________(24 hr.) YOUR NAME:________________________

Make notes below to indicate anything unusual that happened including the subject's coffee consumption and "nodding off." Please note the time at which the event happened.

EXERCISE NAME:________________________ TIME STARTED:____________(24 hr.)

TIME ENDED:_______________(24 hr.) YOUR NAME:________________________

Make notes below to indicate anything unusual that happened including the subject's coffee consumption and "nodding off." Please note the time at which the event happened.

*EXIT INTERVIEW**

For Subject#___________________________
(use code number from *Run Description Form*).

Investigator is to read questions, subject to respond on his own document.

This interview is completely confidential; it will not be shared with your employer. Your responses will be coded so that your name is not attached. Please remember that this study is being done because we are especially concerned about the personal safety of engineers like yourself.

1. How well rested did you feel when you began today's shift?
   [] Well rested
   [] Moderately rested
   [] Slightly rested
   [] Not at all rested

2. How much trouble did you have going to sleep last night?
   [] None
   [] Slight
   [] Moderate
   [] Considerable

3. How do you feel right now?
   [] Fully alert, wide awake, extremely peppy
   [] Very lively, responsive, but not at peak
   [] OK, somewhat fresh
   [] A little tired, less than fresh
   [] Moderately tired, let down
   [] Extremely tired, very difficult to concentrate
   [] Completely exhausted, ready to drop

4. Sometimes, when people are tired, they "blank out" or "doze off" for just a brief moment. Were there times during today's shift when this happened to you?
   [] No, not at all.
   [] Possibly, not really sure.
   [] At least once, no more than 2 or 3 times.
   [] Yes, more than 2 or 3 times.

5. During today's shift, you ran on two districts. On which of them did you find it *EASY TO STAY AWAKE*? (You may check more than one box.)
   [] Rochelle
   [] Davis Junction

] No real difference, they were all about the same

6. During today's shift, you ran on two districts. On which of them did you find it ***HARD*** *TO STAY AWAKE*? (You may check more than one box.)
   [] Rochelle
   [] Davis Junction
   [] Sherman Hill
   [] No real difference, they were all about the same.

7. Here are some of the things you had to do to run the train. Check any activities that made it ***EASIER*** *TO STAY AWAKE*. (You may check more than one box.)
   [] Starting
   [] Accelerating
   [] Negotiating (managing slack while maintaining a specific speed)
   [] Slowing
   [] Stopping
   [] No real difference, they were all about the same.

8. Here are some of the things you had to do to run the train. Check any activities that made it ***HARDER*** *TO STAY AWAKE*. (You may check more than one box.)
   [] Starting
   [] Accelerating
   [] Negotiating (managing slack while maintaining a specific speed)
   [] Slowing
   [] Stopping
   [] No real difference, they were all about the same.

9. Here are the kinds of terrain you had to run the train over. Check any type of terrain that made it ***EASIER*** *TO STAY AWAKE*. (You may check more than one box.)
   [] Level terrain
   [] Light ascending grades
   [] Heavy ascending grades
   [] Light descending grades
   [] Heavy descending grades
   [] Hogbacks (light hill crests)
   [] Heavy hill crests
   [] Sags
   [] No real difference, they were all about the same.

10. Here are the kinds of terrain you had to run the train over. Check any type of terrain that made it ***HARDER TO STAY AWAKE***. (You may check more than one box.)
[] Level terrain
[] Light ascending grades
[] Heavy ascending grades
[] Light descending grades
[] Heavy descending grades
[] Hogbacks (light hill crests)
[] Heavy hill crests
[] Sags
[] No real difference, they were all about the same.

11. If today's shift had happened in the real world, would it have been easier or harder to stay alert?
[] It would have been EASIER to stay alert in the real world, because:

____

____

It would have been HARDER to stay alert in the real world because:

____

____

[] There was no difference in alertness between today's shift and the real world.

Was there any time in today's shift that you feel that you could have made a serious mistake because you were too tired?
[] Yes, I could have made a mistake because I was too tired, but only one or two times.
[] Yes, there were many times I could have made a serious mistake because I was too tired.
[] No, I never was so tired that it would have caused me to make a mistake.

If you used the temperature pill and recorder, did you feel that your performance was affected by them?
[] No, the use of the pill and recorder didn't affect my performance in any way.
[] Yes, the pill and recorder affected my performance, but I'm not sure how much.
[] I feel I didn't do as well as I might have because of the pill and recorder.
[] I feel I did better than I might have otherwise because of the pill and recorder.

* This document was generated on August 20, 1991 by IIT Research Institute for use in IITRI Task Order No. 9 on Contract DTFR53-82-C-00254 from the U.S. Department of Transportation; Federal Railroad Administration.

Locomotive Crew Fatigue Diary

1. District/Service Codes | 2. ID: ____ | 3. Date ___/___/___ | Time ___:___

Time	4a. Called Railroad	4b. Railroad called	5. Commuting	6. Reported	7. Deadheading	8. Working	9. Sleeping	10. Personal Time
00:00-00:59								
01:00-01:59								
02:00-02:59								
03:00-03:59								
04:00-04:59								
05:00-05:59								
06:00-06:59								
07:00-07:59								
08:00-08:59								
09:00-09:59								
10:00-10:59								
11:00-11:59								
12:00-12:59								
13:00-13:59								
14:00-14:59								
15:00-15:59								
16:00-16:59								
17:00-17:59								
18:00-18:59								
19:00-19:59								
20:00-20:59								
21:00-21:59								
22:00-22:59								
23:00-23:59								
24:00-24:59								

11. Total number of hours worked today ______________
12. Undesired overtime hours worked today______________
13. Number of fully qualified engineers in cab______________
14. Number of miles on this run ______________________

15. Did you "nod off" during this run?
- [ ] Yes
- [ ] No

16. How much trouble did you have going to sleep ?
- [ ] None
- [ ] Slight
- [ ] Moderate
- [ ] Considerable

17. How well rested did you feel when you awoke from your last sleep period?
- [ ] Well rested
- [ ] Moderately rested
- [ ] Slightly rested
- [ ] Not at all rested

18. Check box which describes how you feel right now.
- [ ] Fully alert, wide awake, extremely peppy
- [ ] Very lively, responsive, but not at peak
- [ ] OK, somewhat fresh
- [ ] A little tired, less than fresh
- [ ] moderately tired , let down
- [ ] Extremely tired, very difficult to concentrate
- [ ] Completely exhausted, ready to drop

19. Comments:

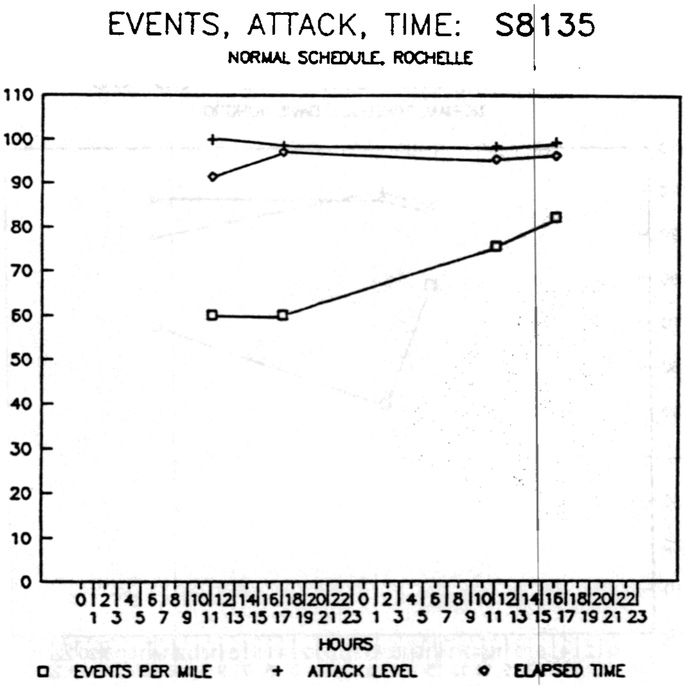
APPENDIX D

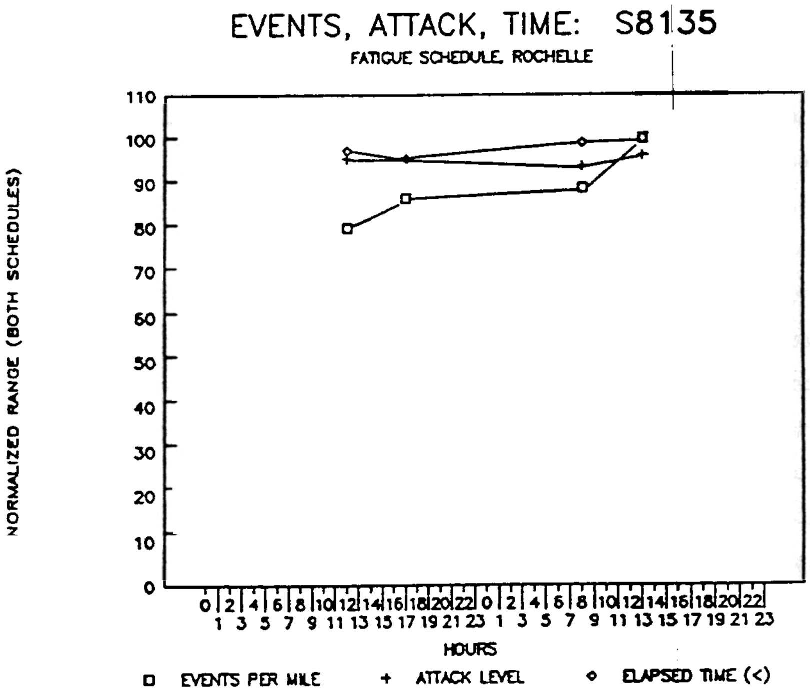
This appendix contains the graphs of errors per mile, attack, and elapsed time for each subject for each territory and each schedule (normal versus fatigue). The graphs are arranged to show errors per mile, attack figures and elapsed time for each subject organized on the basis of schedule and territory.

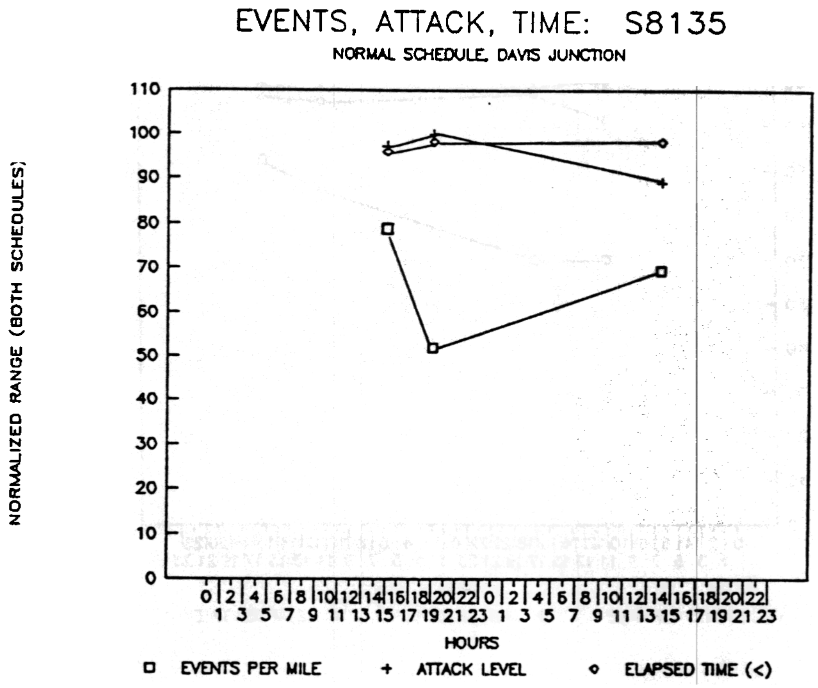
Each graph shows normalized performance figures for the runs made on the indicated territory by a subject. The normalization (conversion to percentage) is based on an individual's performance figures rather than group figures. This choice to normalize on the individual rather than the group was made as a result of the limited amount of data generated by the small number of subjects in this pilot study and by the consequent need to show how individual performance was affected by the passage of time. The time frame covers the two day period of the indicated schedule. The data points on each graph are connected by a line to make differences more apparent. It should be remembered, however, that the subjects alternated runs on a fixed pattern (Rochelle, then Davis Junction). The investigator chose not to mix data from the two runs on one graph since the difficulty of the runs was apparently different. This difference in difficulty was determined by actual error rates as well as by the experienced judgment of the subjects and observers. The normalization of error rates means that a subject's highest error rate for a territory = 100%.

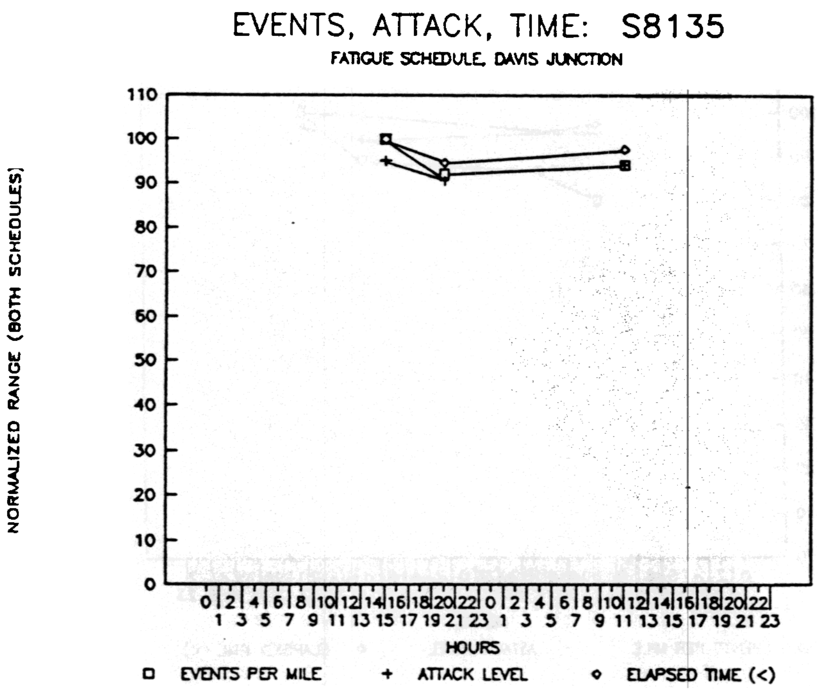
Within each graph, elapsed time is shown in an efficiency orientation; that is, shorter times move in a positive direction, or upward, while longer times move downward. This presentation is to allow the comparison of attack figure and elapsed time. If an engineer operates efficiently, increases in attack should produce decreases in elapsed time (without increases in error rates). In other words, the attack figure and elapsed time figure should track each other in direction while error rate remains stable or moves in an opposite direction.

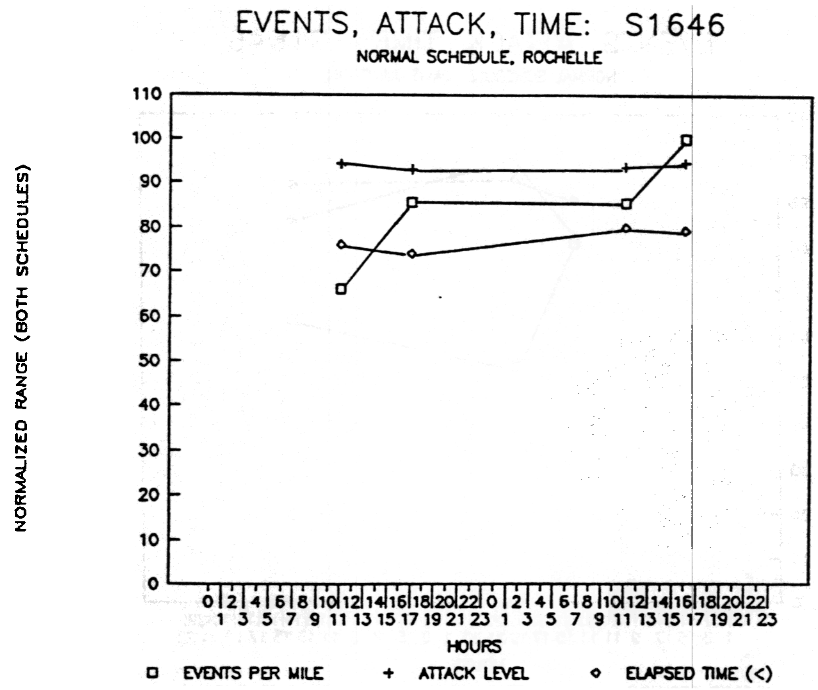
Referring to the graph on page D-2, Subject S8135 slightly increased attack on the second normal schedule run of Davis Junction on the first day. In this case, elapsed time also improved by a proportional amount, while the error rate fell markedly. This would be an example of improved efficiency.


EVENTS, ATTACK, TIME: S8135
NORMAL SCHEDULE, ROCHELLE
110
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 0 2 4 6 8 10 12 14 16 18 20 22
1 3 5 7 9 11 13 15 17 19 21 23 1 3 5 7 9 11 13 15 17 19 21 23
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME

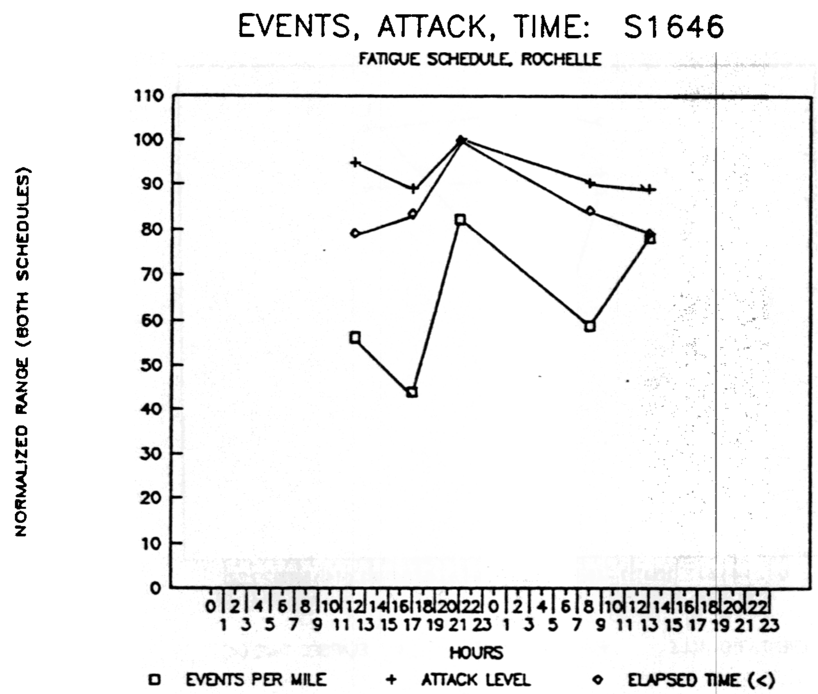

EVENTS, ATTACK, TIME: S8135
FATIGUE SCHEDULE, ROCHELLE
NORMALIZED RANGE (BOTH SCHEDULES)
110
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 0 2 4 6 8 10 12 14 16 18 20 22
1 3 5 7 9 11 13 15 17 19 21 23 1 3 5 7 9 11 13 15 17 19 21 23
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME (<)


EVENTS, ATTACK, TIME: S8135
NORMAL SCHEDULE, DAVIS JUNCTION
NORMALIZED RANGE (BOTH SCHEDULES)
110
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME (<)

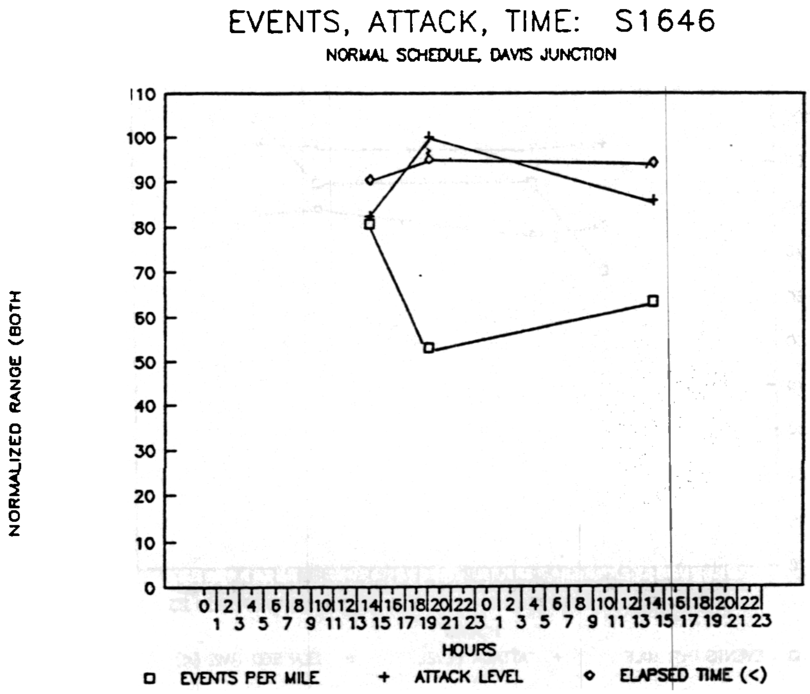

EVENTS, ATTACK, TIME: S8135
FATIGUE SCHEDULE, DAVIS JUNCTION
NORMALIZED RANGE (BOTH SCHEDULES)
110
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME (<)

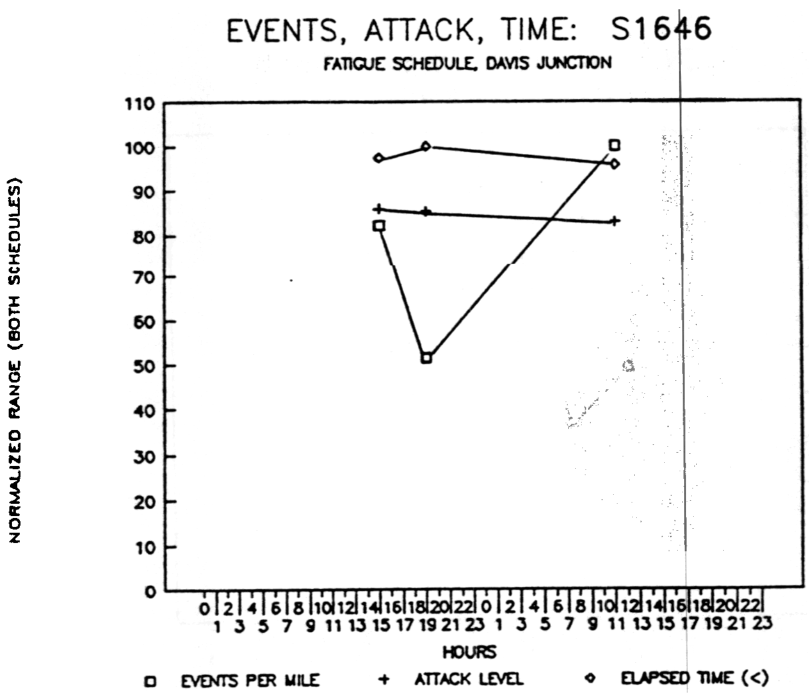


EVENTS, ATTACK, TIME: S1646
NORMAL SCHEDULE, ROCHELLE
NORMALIZED RANGE (BOTH SCHEDULES)
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME (<)



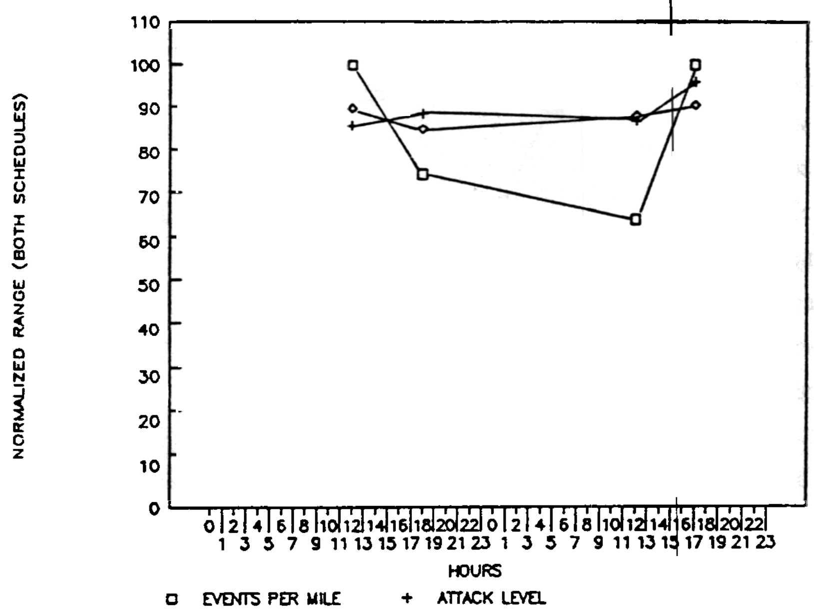
EVENTS, ATTACK, TIME: S1646
FATIGUE SCHEDULE, ROCHELLE
NORMALIZED RANGE (BOTH SCHEDULES)
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME (<)


EVENTS, ATTACK, TIME: S1646
NORMAL SCHEDULE, DAVIS JUNCTION
NORMALIZED RANGE (BOTH
110
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 0 2 4 6 8 10 12 14 16 18 20 22
1 3 5 7 9 11 13 15 17 19 21 23 1 3 5 7 9 11 13 15 17 19 21 23
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME (<)


EVENTS, ATTACK, TIME: S1646
FATIGUE SCHEDULE, DAVIS JUNCTION
NORMALIZED RANGE (BOTH SCHEDULES)
110
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 0 2 4 6 8 10 12 14 16 18 20 22
1 3 5 7 9 11 13 15 17 19 21 23 1 3 5 7 9 11 13 15 17 19 21 23
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME (<)

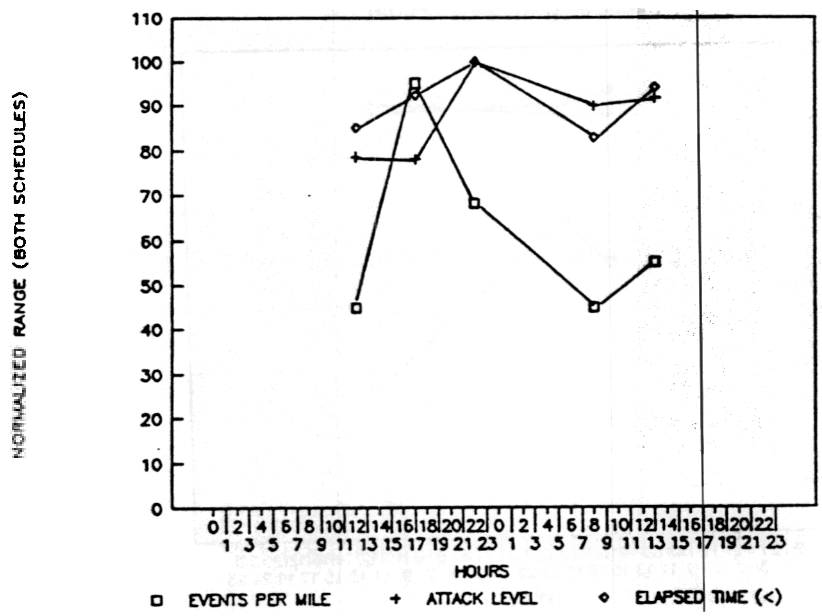
EVENTS, ATTACK, TIME: S3560

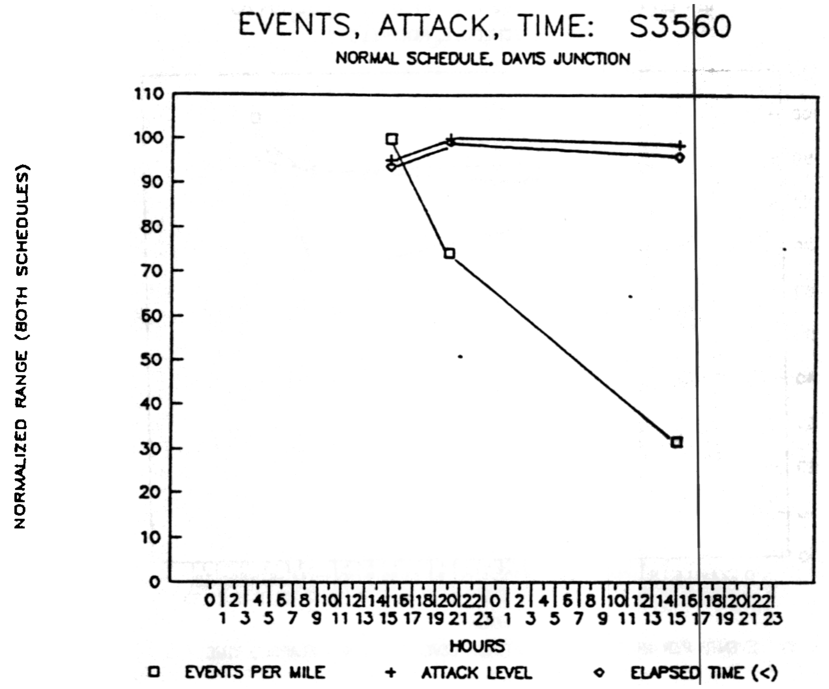
NORMAL SCHEDULE, ROCHELLE

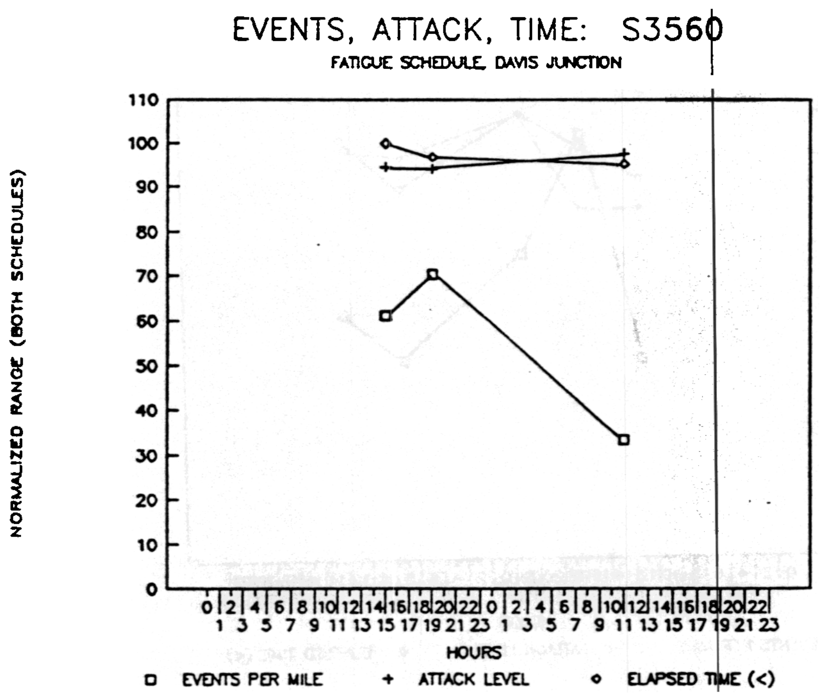


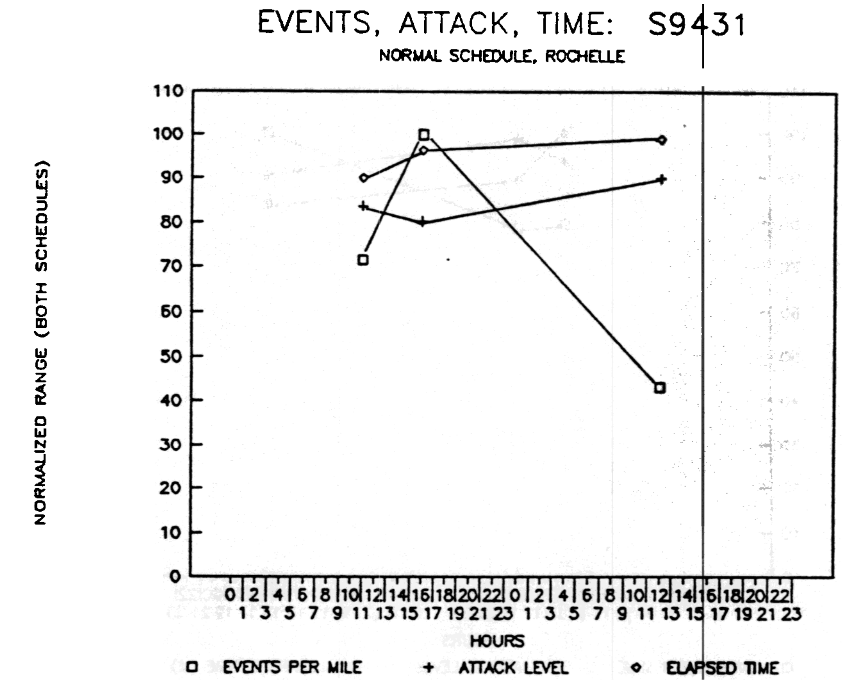
EVENTS, ATTACK, TIME:

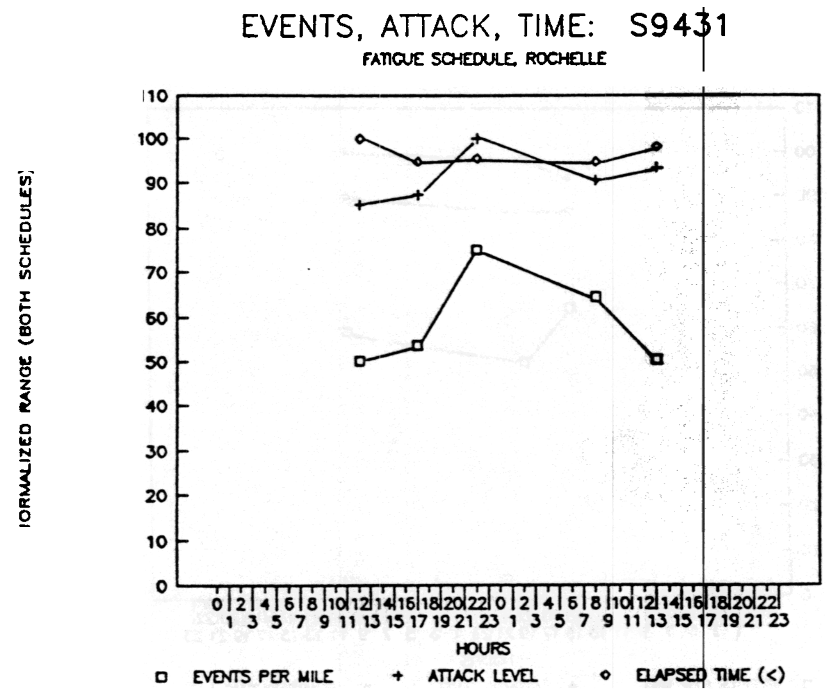
FATIGUE SCHEDULE, ROCHELLE

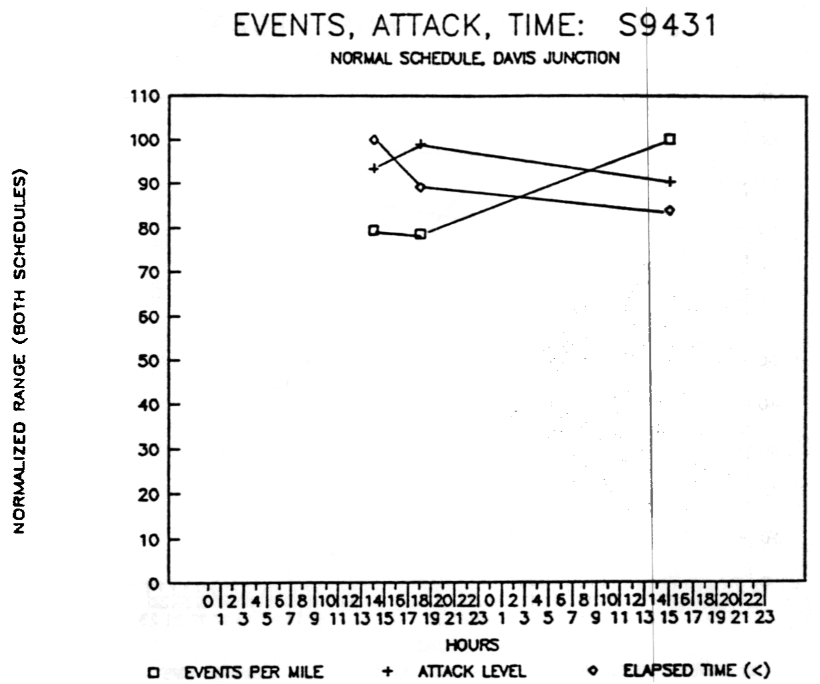


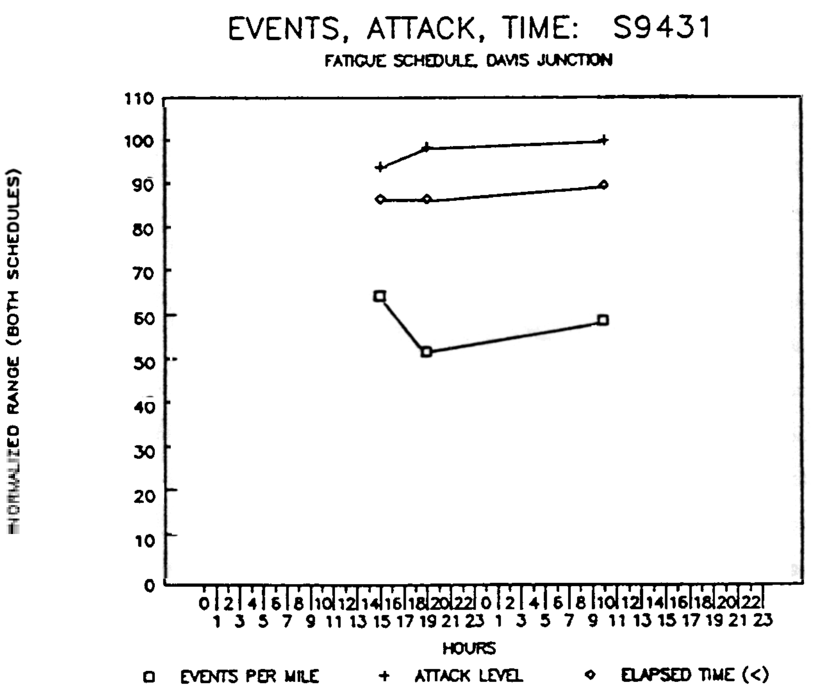

EVENTS, ATTACK, TIME: S3560
NORMAL SCHEDULE, DAVIS JUNCTION
NORMALIZED RANGE (BOTH SCHEDULES)
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME (<)


EVENTS, ATTACK, TIME: S3560
FATIGUE SCHEDULE, DAVIS JUNCTION
NORMALIZED RANGE (BOTH SCHEDULES)
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME (<)


EVENTS, ATTACK, TIME: S9431
NORMAL SCHEDULE, ROCHELLE
NORMALIZED RANGE (BOTH SCHEDULES)
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME


EVENTS, ATTACK, TIME: S9431
FATIGUE SCHEDULE, ROCHELLE
NORMALIZED RANGE (BOTH SCHEDULES)
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME (<)


EVENTS, ATTACK, TIME: S9431
NORMAL SCHEDULE, DAVIS JUNCTION
NORMALIZED RANGE (BOTH SCHEDULES)
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME (<)


EVENTS, ATTACK, TIME: S9431
FATIGUE SCHEDULE, DAVIS JUNCTION
NORMALIZED RANGE (BOTH SCHEDULES)
HOURS
EVENTS PER MILE
ATTACK LEVEL
ELAPSED TIME (<)

APPENDIX E

This appendix contains the sleep diary information for the subjects reduced to single bar records for each date on which records were kept.

SLEEP DIARY CHART

SUBJECT: 9431

WWWW = WORK
SSSS = SLEEP
(blank) = PERSONAL

Time	date> 12/3	4	5	6	7	8	9	12/12	13	14	15
0000	SSSS	WWWW	WWWW	WWWW	WWWW				WWWW	WWWW	SSSS
0100	SSSS	WWWW	WWWW	WWWW	WWWW		SSSS	SSSS	WWWW		SSSS
0200	SSSS	WWWW	WWWW	WWWW	WWWW	SSSS	SSSS	SSSS	WWWW		SSSS
0300	SSSS	WWWW	WWWW	WWWW	WWWW	SSSS	SSSS	SSSS	WWWW		SSSS
0400		WWWW			WWWW	SSSS	SSSS	SSSS		SSSS	SSSS
0500	SSSS		SSSS		WWWW	SSSS	SSSS	SSSS		SSSS	SSSS
0600	SSSS	SSSS	SSSS	SSSS			SSSS	SSSS	SSSS		
0700	SSSS	SSSS	SSSS	SSSS	SSSS		SSSS	SSSS	SSSS		
0800	SSSS	SSSS	SSSS	SSSS	SSSS	SSSS	SSSS		SSSS		
0900	SSSS	SSSS	SSSS	SSSS	SSSS	SSSS			SSSS		
1000		SSSS	SSSS	SSSS		SSSS			SSSS		
1100		SSSS							SSSS		
1200											
1300											
1400											
1500						WWWW	WWWW	WWWW	WWWW		
1600	WWWW	WWWW	WWWW	WWWW	SSSS	WWWW	WWWW	WWWW	WWWW		
1700	WWWW	WWWW	WWWW	WWWW	SSSS	WWWW	WWWW	WWWW	WWWW		
1800	WWWW	WWWW	WWWW	WWWW	SSSS	WWWW	WWWW	WWWW	WWWW		
1900	WWWW	WWWW	WWWW	WWWW	SSSS	WWWW	WWWW	WWWW	WWWW		
2000	WWWW	WWWW	WWWW	WWWW		WWWW	WWWW	WWWW	WWWW		
2100	WWWW	WWWW	WWWW	WWWW		WWWW	WWWW	WWWW	WWWW		
2200	WWWW	WWWW	WWWW	WWWW		WWWW	WWWW	WWWW	WWWW		
2300	WWWW	WWWW	WWWW	WWWW		WWWW	WWWW	WWWW	WWWW		
2300	WWWW	WWWW	WWWW	WWWW			WWWW	WWWW	WWWW		

SLEEP DIARY CHART

SUBJECT: 3560

WWWW = WORK
SSSS = SLEEP
(blank) = PERSONAL

Time	date> 12/26	27	28	29	30	1/4	5	6	7	8
0000		SSSS				SSSS	SSSS	SSSS	SSSS	SSSS
0100		SSSS				SSSS	SSSS	SSSS	SSSS	SSSS
0200		SSSS				SSSS	SSSS	SSSS	SSSS	SSSS
0300		SSSS		SSSS	SSSS	SSSS	SSSS	SSSS	SSSS	SSSS
0400				SSSS	SSSS	SSSS	SSSS	SSSS		SSSS
0500				SSSS	SSSS	SSSS		SSSS	WWWW	SSSS
0600			WWWW	SSSS	SSSS			SSSS	WWWW	SSSS
0700			WWWW		SSSS		WWWW		WWWW	
0800	WWWW		WWWW		SSSS		WWWW		WWWW	
0900	WWWW				SSSS		WWWW	WWWW	WWWW	
1000	WWWW						WWWW	WWWW		
1100	WWWW						WWWW	WWWW		
1200	WWWW						WWWW	WWWW		
1300	WWWW						WWWW	WWWW		
1400	WWWW						WWWW	WWWW		
1500						SSSS	WWWW	WWWW		
1600		WWWW			WWWW	SSSS	WWWW	WWWW		
1700		WWWW			WWWW	SSSS	WWWW			
1800		WWWW	SSSS	SSSS	WWWW	SSSS	WWWW			
1900			SSSS	SSSS	WWWW					
2000	SSSS		SSSS	SSSS	WWWW					
2100	SSSS		SSSS	SSSS	WWWW					
2200	SSSS		SSSS	SSSS	WWWW			SSSS		SSSS
2300	SSSS	SSSS			WWWW	SSSS		SSSS	SSSS	SSSS

SLEEP DIARY CHART

SUBJECT: 1646

WWWW = WORK
SSSS = SLEEP
(blank) = PERSONAL

Time	12/4	5	6	7	8	9	10	11	14	15	16	17
0000	SSSS	SSSS	SSSS	SSSS	WWWW	WWWW	SSSS	SSSS	SSSS	SSSS	WWWW	SSSS
0100	SSSS	SSSS	SSSS	SSSS	WWWW	WWWW	SSSS	SSSS	SSSS	SSSS	SSSS	SSSS
0200	SSSS	SSSS	SSSS	SSSS		WWWW	SSSS	SSSS	SSSS	SSSS	SSSS	SSSS
0300	SSSS	SSSS	SSSS	SSSS		WWWW		SSSS	SSSS	SSSS	SSSS	SSSS
0400	SSSS	SSSS		SSSS	SSSS	WWWW		SSSS	SSSS	SSSS	SSSS	SSSS
0500	SSSS		WWWW	SSSS	SSSS	WWWW	WWWW	WWWW	SSSS	SSSS		SSSS
0600			WWWW	SSSS	SSSS	WWWW	WWWW	WWWW	SSSS	SSSS	WWWW	WWWW
0700	WWWW		WWWW		SSSS	WWWW	WWWW	WWWW	SSSS		WWWW	WWWW
0800	WWWW	WWWW	WWWW		SSSS	WWWW	WWWW	WWWW			WWWW	WWWW
0900	WWWW	WWWW	WWWW			WWWW	WWWW	WWWW			WWWW	WWWW
1000	WWWW	WWWW	WWWW				WWWW	WWWW			WWWW	WWWW
1100	WWWW	WWWW	WWWW				WWWW	WWWW			WWWW	WWWW
1200	WWWW	WWWW	WWWW			SSSS	WWWW	WWWW			WWWW	WWWW
1300	WWWW	WWWW	WWWW			SSSS	WWWW	WWWW			WWWW	WWWW
1400	WWWW	WWWW	WWWW			SSSS	WWWW	WWWW			WWWW	WWWW
1500	WWWW	WWWW	WWWW			SSSS	WWWW	WWWW	WWWW	WWWW	WWWW	WWWW
1600		WWWW	WWWW		SSSS		WWWW	WWWW	WWWW	WWWW	WWWW	WWWW
1700		WWWW	WWWW		SSSS		WWWW	WWWW	WWWW	WWWW	WWWW	WWWW
1800		WWWW		WWWW	SSSS			WWWW	WWWW	WWWW		
1900				WWWW	SSSS			WWWW	WWWW	WWWW		
2000				WWWW	SSSS				WWWW	WWWW		
2100				WWWW	SSSS				WWWW	WWWW		
2200	SSSS			WWWW		SSSS			WWWW	WWWW		
2300	SSSS	SSSS		WWWW		SSSS		SSSS	WWWW	WWWW		
2300	SSSS	SSSS	SSSS		WWWW	SSSS	SSSS	SSSS		WWWW		

SLEEP DIARY CHART

SUBJECT: 8135

WWWW = WORK
SSSS = SLEEP
(blank) = PERSONAL

Time	12/28	29	30	31	1/1	2	3	4	5	6	8	9	10	11	12	13
0000		SSSS	WWWW	WWWW		SSSS		SSSS	SSSS		SSSS	SSSS	SSSS	SSSS	SSSS	SSSS
0100		SSSS		WWWW		SSSS			SSSS		SSSS	SSSS	SSSS	SSSS	SSSS	SSSS
0200		SSSS				SSSS	WWWW		SSSS	SSSS	SSSS	SSSS	SSSS	SSSS	SSSS	SSSS
0300		SSSS	SSSS		SSSS	SSSS	WWWW		SSSS	SSSS		SSSS	SSSS	SSSS	SSSS	SSSS
0400		SSSS	SSSS	SSSS	SSSS	SSSS	WWWW	WWWW	SSSS	SSSS		SSSS	SSSS	SSSS	SSSS	SSSS
0500		SSSS	SSSS	SSSS	SSSS	SSSS	WWWW	WWWW	SSSS	SSSS	SSSS	SSSS	SSSS	SSSS	SSSS	SSSS
0600		SSSS	SSSS	SSSS	SSSS		WWWW	WWWW	SSSS		SSSS	SSSS			SSSS	
0700		SSSS	SSSS	SSSS	SSSS			WWWW	SSSS		SSSS			WWWW	SSSS	
0800		SSSS	SSSS	SSSS	SSSS		SSSS	WWWW	SSSS		SSSS			WWWW	SSSS	
0900			SSSS	SSSS	SSSS		SSSS	WWWW	SSSS					WWWW		
1000			SSSS	SSSS	SSSS		SSSS	WWWW	SSSS					WWWW		
1100					SSSS		SSSS	WWWW	SSSS				WWWW	WWWW		
1200					SSSS		SSSS	WWWW	SSSS				WWWW	WWWW		
1300							SSSS	WWWW					WWWW	WWWW		
1400							SSSS						WWWW	WWWW		
1500					SSSS								WWWW	WWWW		
1600			WWWW		SSSS								WWWW			
1700			WWWW										WWWW			
1800		WWWW	WWWW										WWWW			
1900		WWWW	WWWW										WWWW			
2000		WWWW	WWWW													
2100		WWWW	WWWW													
2200		WWWW	WWWW				SSSS									
2300	SSSS	WWWW	WWWW				SSSS									
2300	SSSS	WWWW	WWWW			SSSS	SSSS	SSSS			SSSS	SSSS	SSSS			

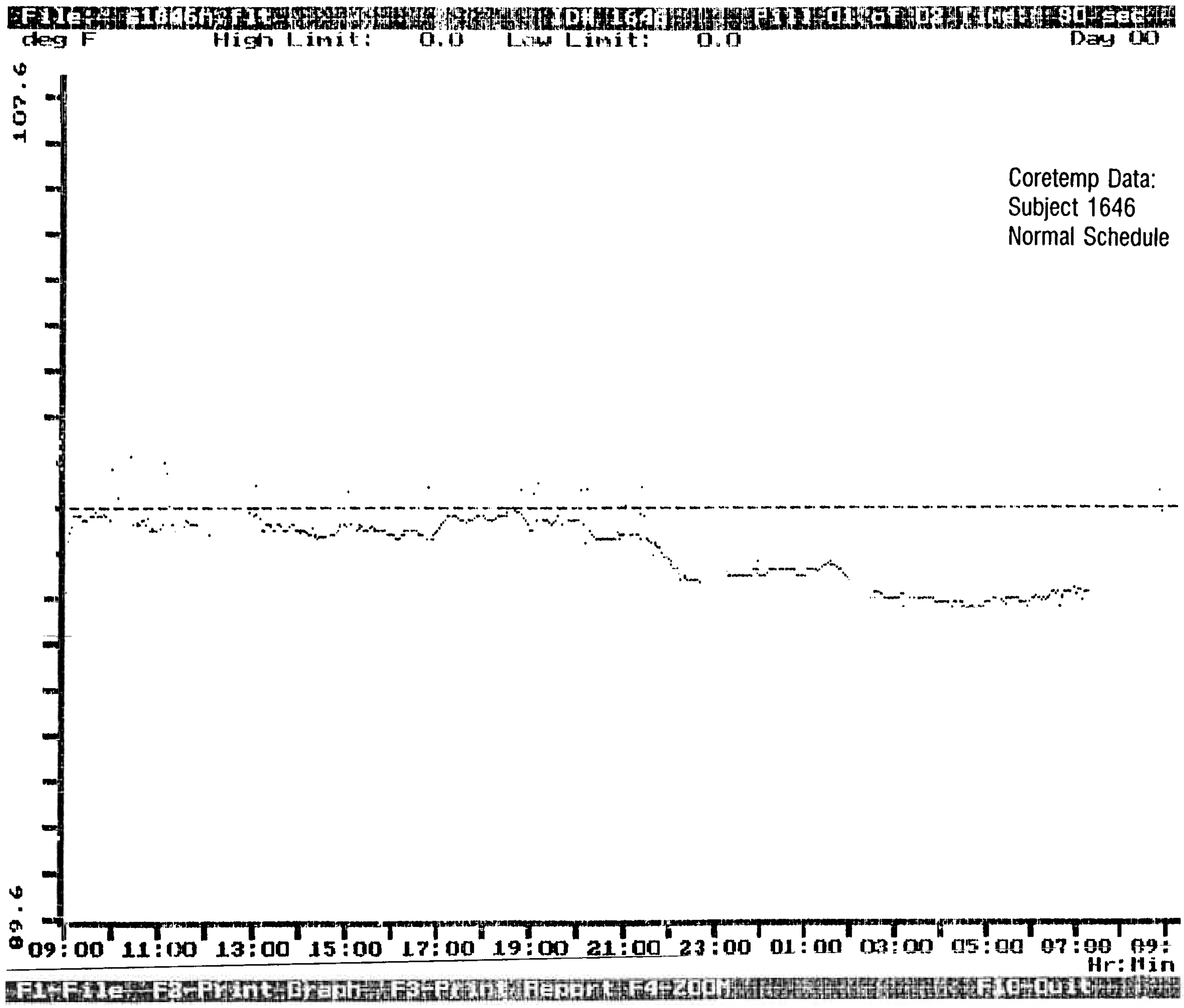
E-4

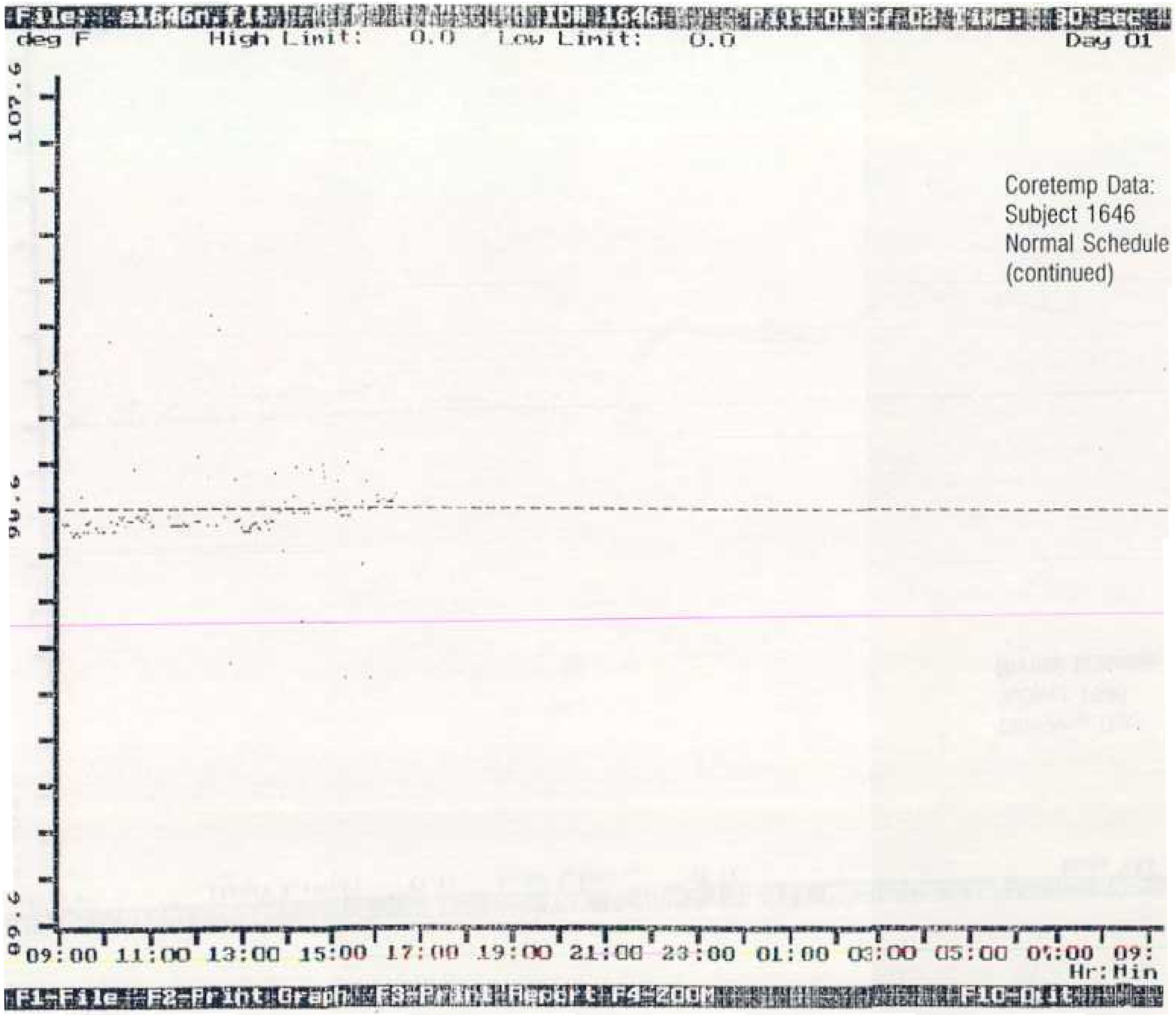
APPENDIX F

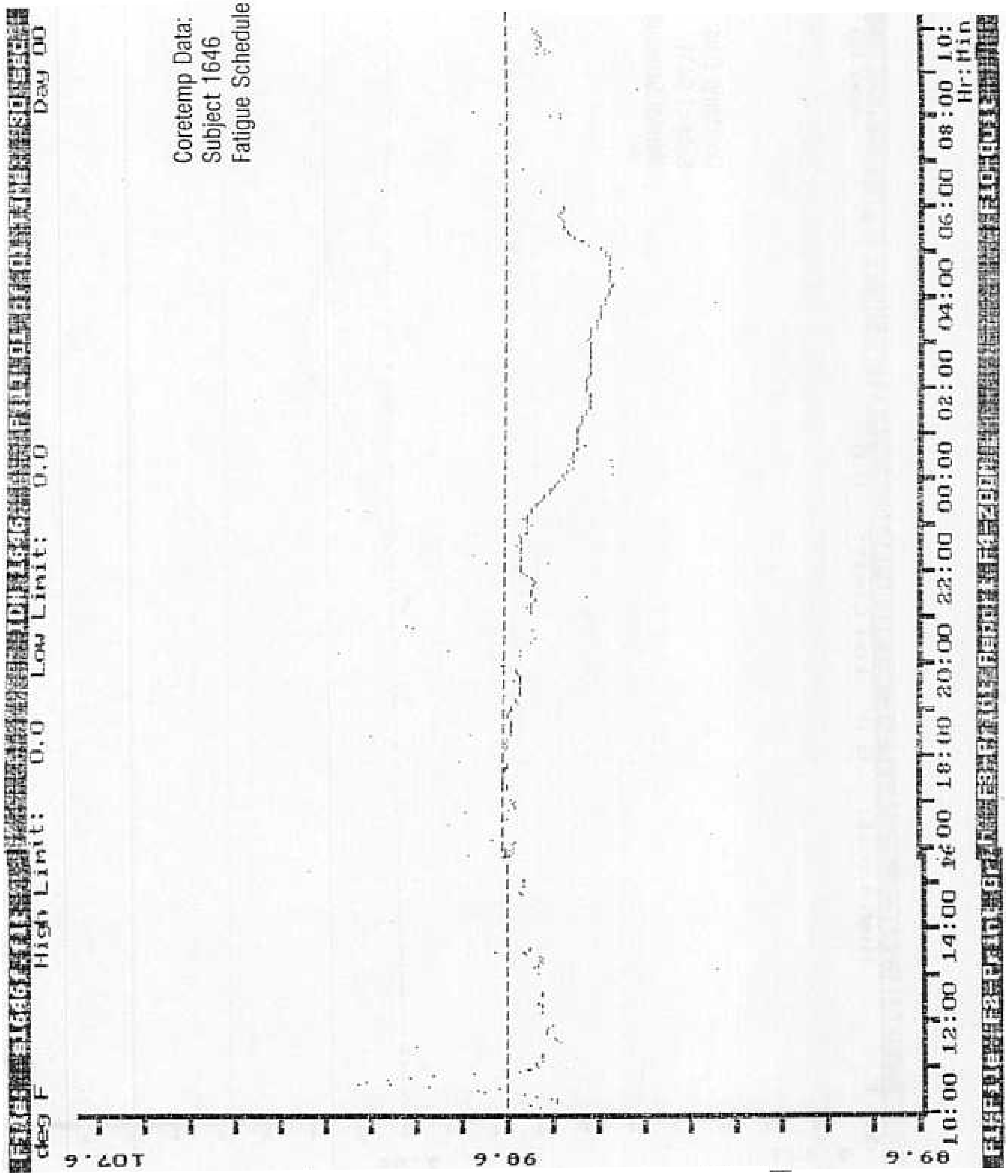
This appendix contains the core body temperature traces for those subjects who had data available.

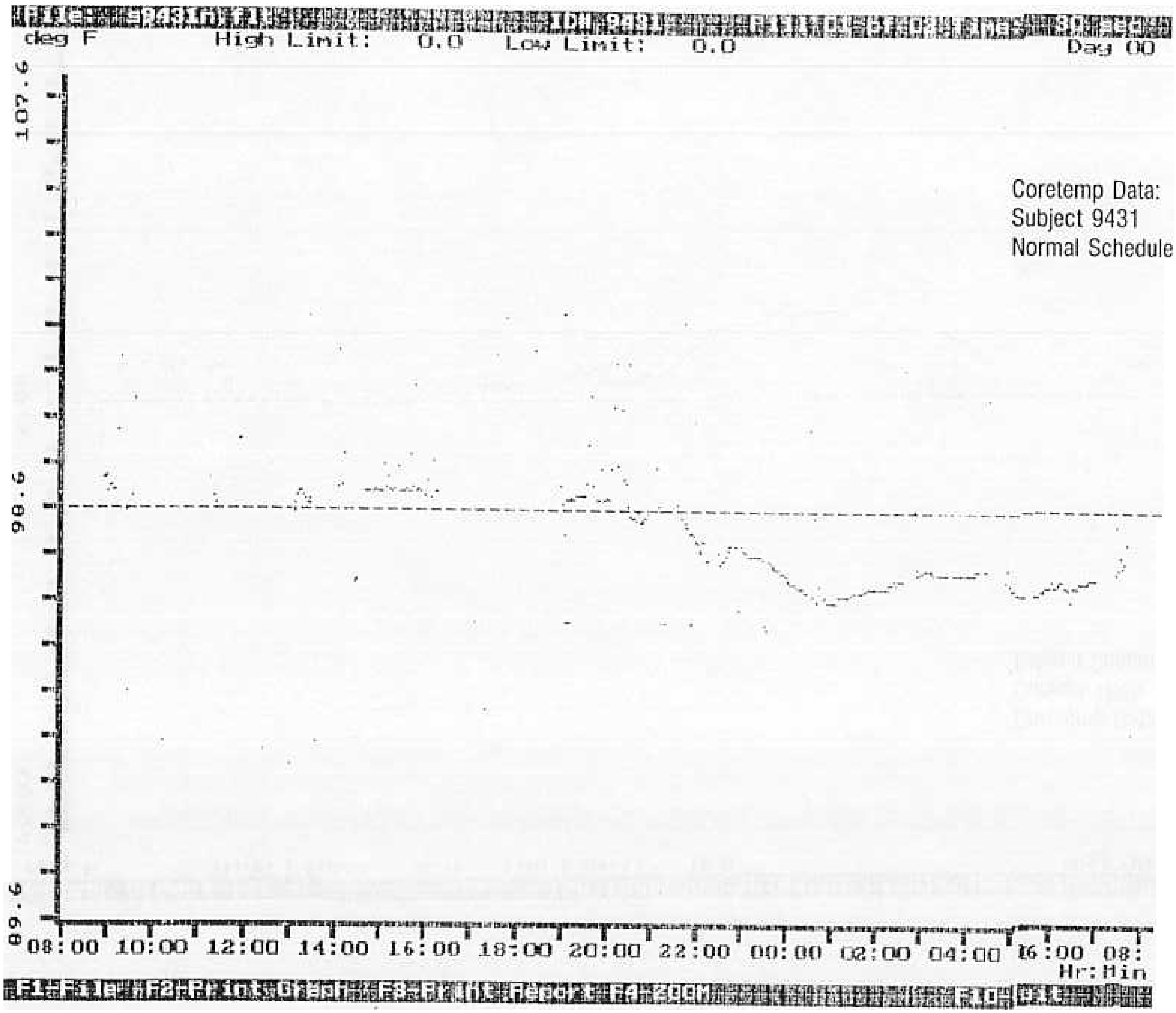
The normal schedule data for two subjects is incomplete; S8135 is truncated and the data for S3560 is missing due to apparent recording malfunctions.

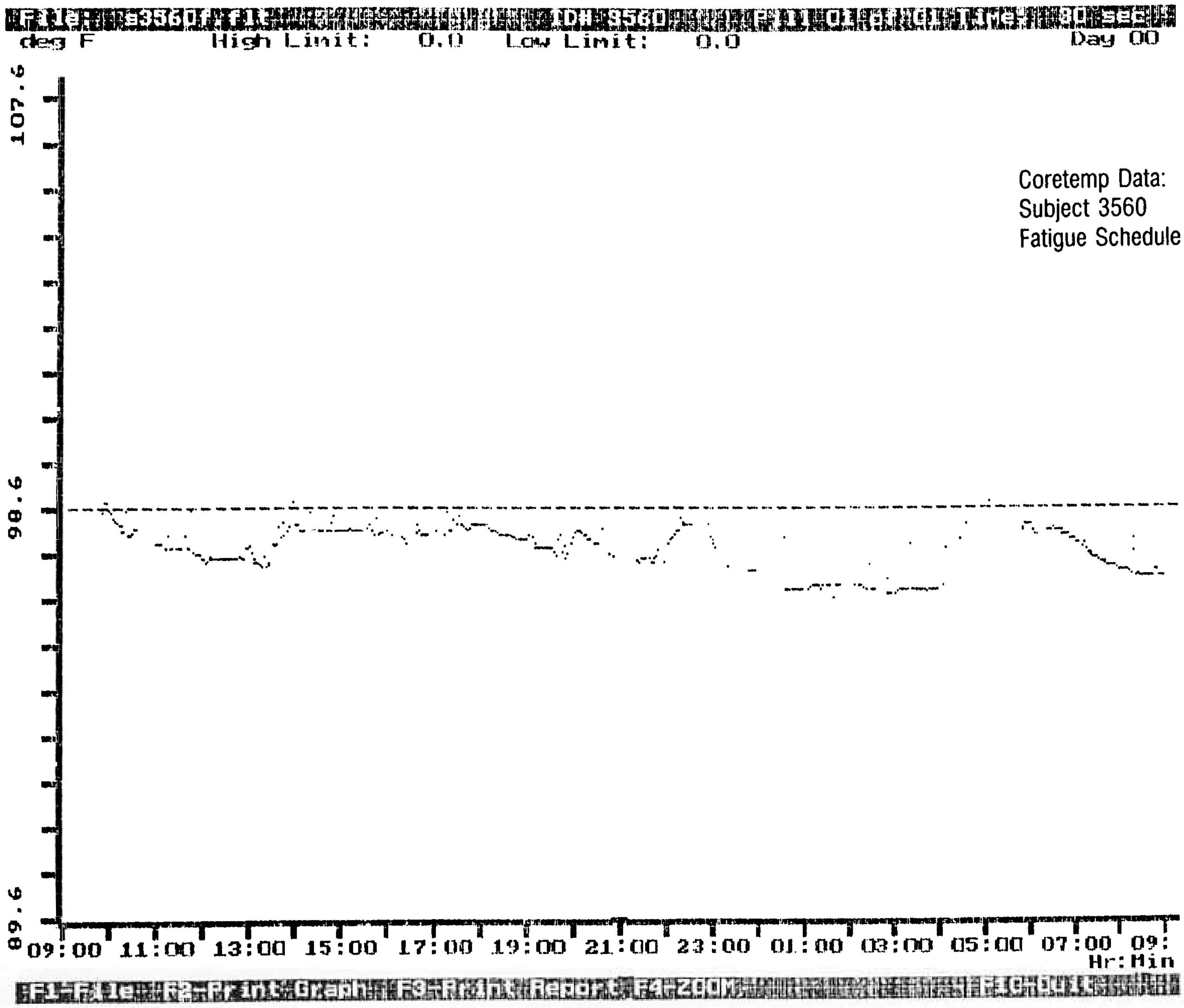
The fatigue schedule data for S9431 was too erratic for use, possibly due to a malfunctioning pill or large body mass.

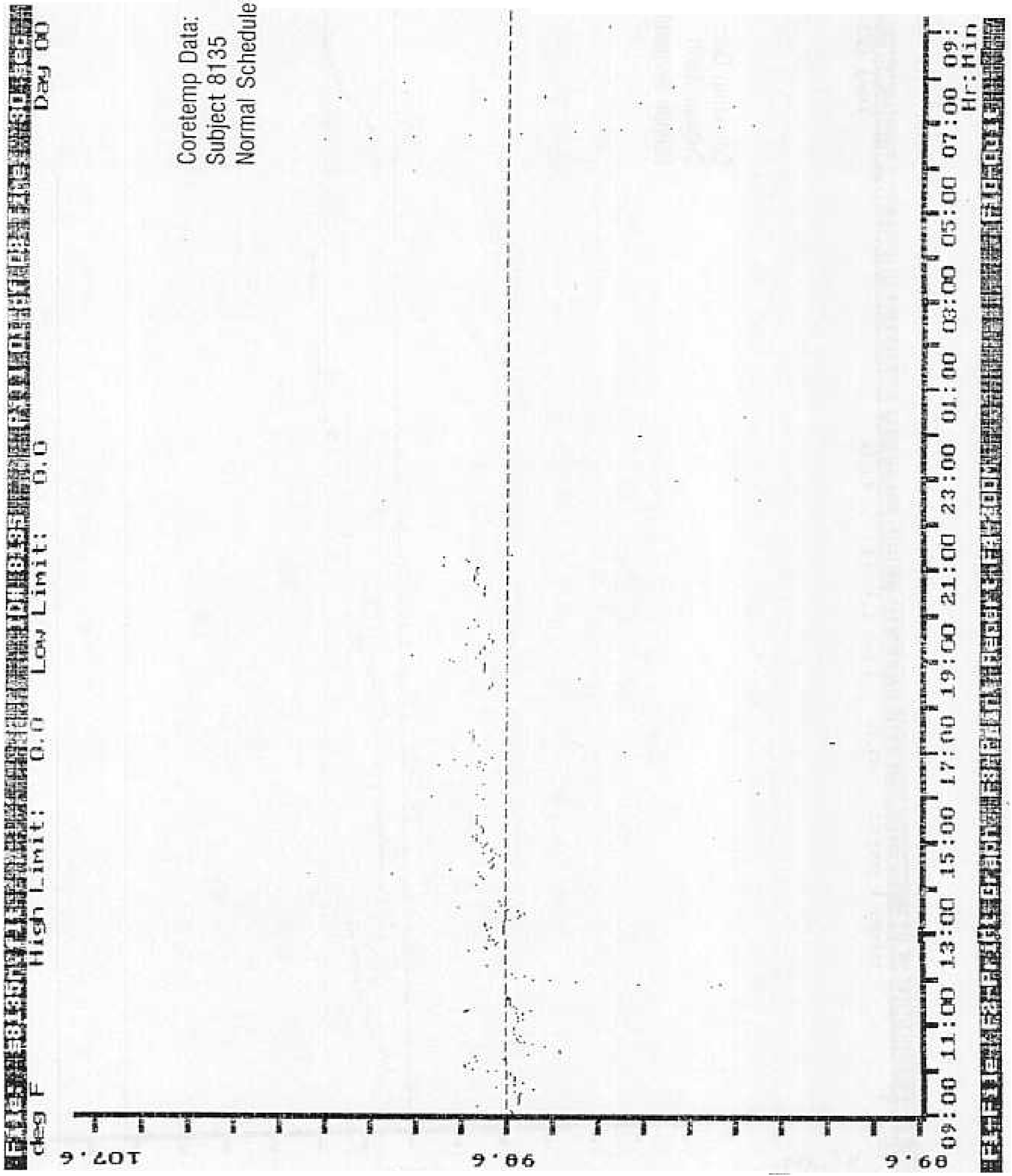

deg F
High Limit: 0.0
Low Limit: 0.0
Day 00
107.6
89.6
Coretemp Data:
Subject 1646
Normal Schedule
09:00 11:00 13:00 15:00 17:00 19:00 21:00 23:00 01:00 03:00 05:00 07:00 09:
Hr:Min
F1-File F2-Print Graph F3-Print Report F4-ZOOM F10-Quit

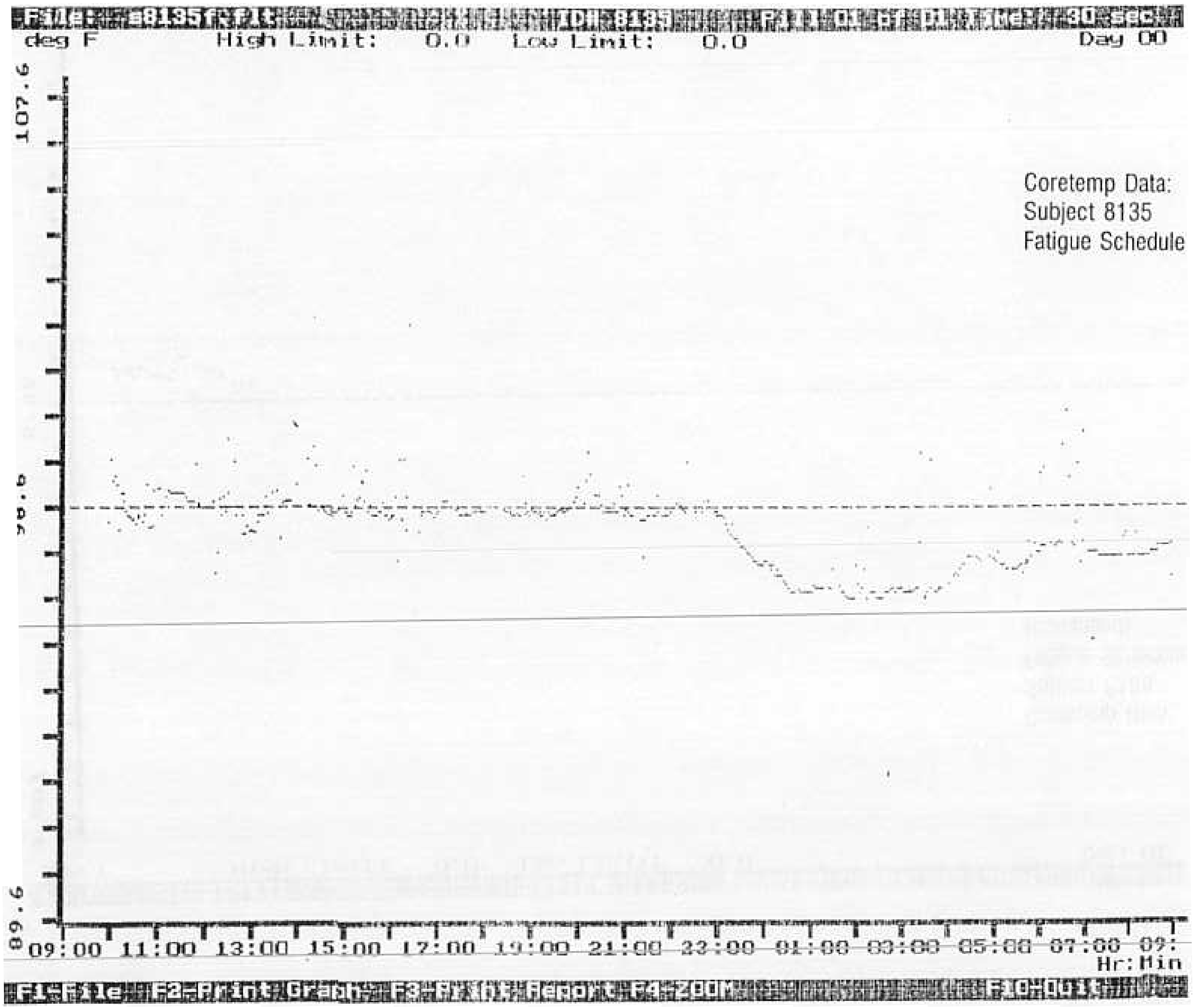

File: s1646n.flt
ID: 1646
30 sec
deg F
High Limit: 0.0
Low Limit: 0.0
Day 01
107.6
98.6
89.6
Coretemp Data:
Subject 1646
Normal Schedule
(continued)
09:00
11:00
13:00
15:00
17:00
19:00
21:00
23:00
01:00
03:00
05:00
07:00
09:
Hr:Min
F1-File
F2-Print Graph
F4-ZOOM
F10-Quit

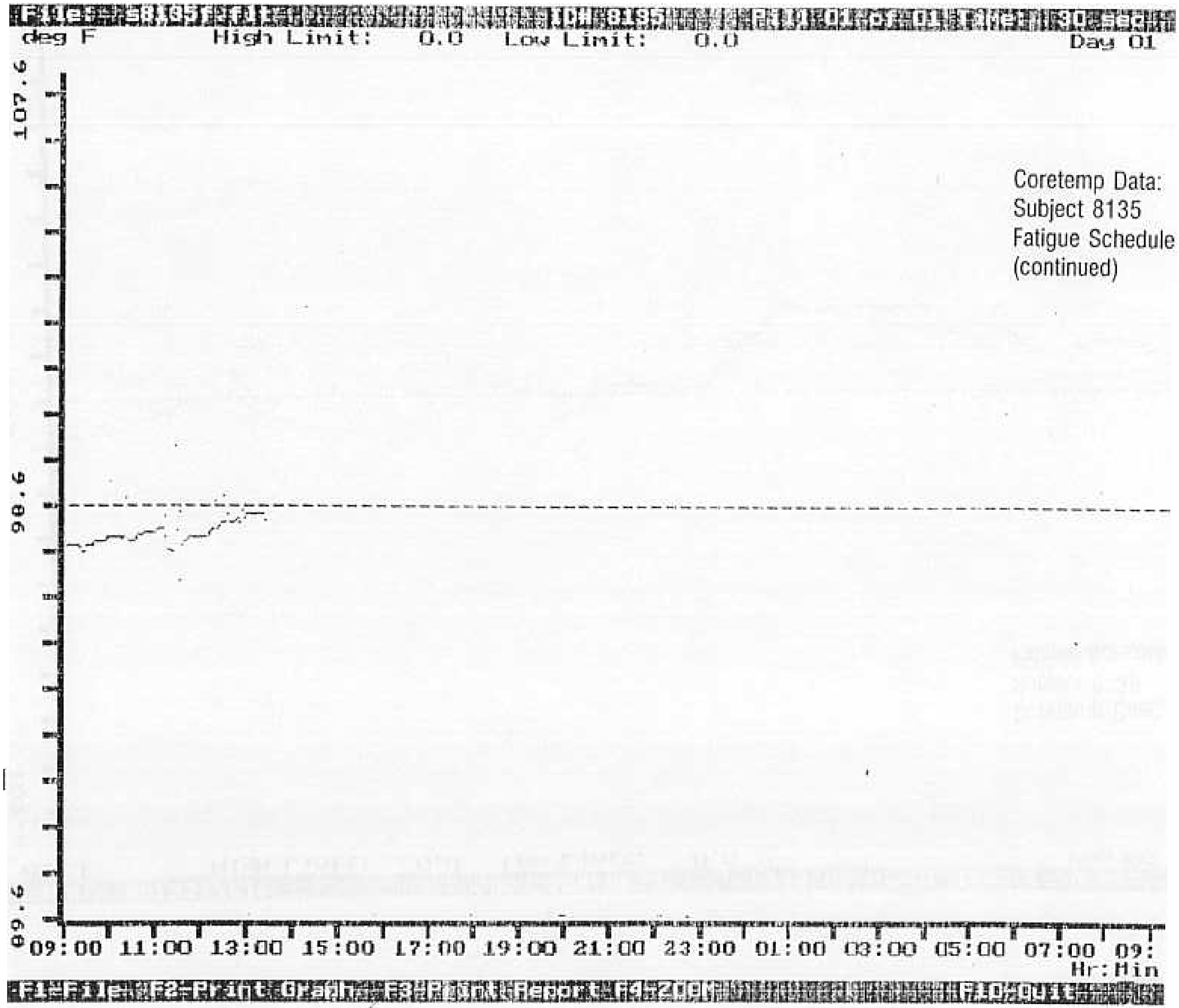

Coretemp Data:
Subject 1646
Fatigue Schedule
High Limit: 0.0
Low Limit: 0.0
Day 00
deg F
107.6
98.6
89.6
10:00 12:00 14:00 16:00 18:00 20:00 22:00 00:00 02:00 04:00 06:00 08:00 10:
Hr:Min


deg F
High Limit: 0.0
Low Limit: 0.0
Day 00
Coretemp Data:
Subject 9431
Normal Schedule
107.6
98.6
89.6
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:
Hr:Min


File: s3560f.flt ID# 3560 Time: 30 sec
deg F High Limit: 0.0 Low Limit: 0.0 Day 00
107.6
98.6
89.6
Coretemp Data:
Subject 3560
Fatigue Schedule
09:00 11:00 13:00 15:00 17:00 19:00 21:00 23:00 01:00 03:00 05:00 07:00 09:
Hr:Min
F1-File F2-Print Graph F3-Print Report F4-ZOOM F10-Quit


Coretemp Data:
Subject 8135
Normal Schedule
deg F
High Limit: 0.0
Low Limit: 0.0
Day 00
107.6
98.6
89.6
09:00 11:00 13:00 15:00 17:00 19:00 21:00 23:00 01:00 03:00 05:00 07:00 09:
Hr:Min


deg F
High Limit: 0.0
Low Limit: 0.0
Day 00
107.6
98.6
89.6
09:00 11:00 13:00 15:00 17:00 19:00 21:00 23:00 01:00 03:00 05:00 07:00 09:
Hr:Min
F1-File F2-Print Graph F3-Print Report F4-ZOOM F10-Quit
Coretemp Data:
Subject 8135
Fatigue Schedule


deg F
High Limit: 0.0
Low Limit: 0.0
Day 01
107.6
98.6
89.6
09:00 11:00 13:00 15:00 17:00 19:00 21:00 23:00 01:00 03:00 05:00 07:00 09:
Hr:Min
Coretemp Data:
Subject 8135
Fatigue Schedule
(continued)