EVALUATION OF AVIATION MAINTENANCE WORKING ENVIRONMENTS, FATIGUE, AND HUMAN PERFORMANCE

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EXECUTIVE SUMMARY

This study characterizes selected environmental conditions of the aviation maintenance workplace and the amount of sleep obtained by aviation maintenance personnel. One-hundred technicians from three large carriers voluntarily wore sophisticated measurement devices to monitor temperature, lighting, and sound levels while working. In addition, the research measured sleep conditions, assessed over a 2-week, 24-hour/day duration. Results showed summer temperature average of 86°F (30°C) with ranges from 59°F (15°C) to 130°F (54°C). Approximate average daily sleep duration for maintenance personnel was 5 hours. Five-hundred airline maintenance personnel responded to a 41-item questionnaire about fatigue and work conditions. On the whole, respondents did not perceive lack of sleep or fatigue to be a serious challenge in the workplace. Some of the questionnaire response data was not consistent with actual data collected with monitoring devices. This data collection phase sets the stage for a continuing effort to search for a relationship between fatigue and error.

1.0 MEASURING WORK CONDITIONS AND FATIGUE: ACTIVITY TO DATE

Workplace environmental conditions can impact the quality of work performance and worker fatigue. However, each day aviation maintenance workers are sometimes faced with sub-optimal work conditions which contribute to fatigue. When these conditions can be controlled they must be. When such conditions cannot be controlled then the system must help the human to work in a manner that is safe, healthy, efficient, and effective.

In 1989, the National Transportation Safety Board issued recommendations urging all modes of transportation to conduct research on fatigue. Information from this research would help educate workers on the effects of fatigue and to offer proper habits to reduce fatigue or to work safely when fatigue is likely. The result should be a higher level of transportation safety. A large share of the fatigue and sleep research has focused on flight crews (Lauber and Kayten, 1988; Battelle Memorial Institute and JIL Information Systems, 1998) and process control operational environments (Rosenkind, et al., 1996 a & b; Tepas, 1991).

The initial phase of this current phased-study commenced in 1998 (Bosley, Miller, & Watson). That study completed an excellent literature review and analysis of workplace factors and fatigue in maintenance environments. Bosley et al.'s study identified and tested equipment to collect environmental and sleep data in maintenance environments. Bosely et al. selected equipment manufactured by the Mini Mitter Corporation to collect the data in a relatively unobtrusive manner. The devices, pictured in Figure 1, include the Actiwatch and the Mini-Logger. The Mini-Logger,

slightly larger than a pack of cigarettes, collects continuous data on time, temperature, sound level, and light. Volunteers wore the Mini-Logger, in their front pocket during work hours. The Actiwatch was worn at all times, 7 days a week, 24 hours a day. Researchers have found the Actiwatch to be as accurate as the most sophisticated measurement equipment used in sleep research (Kushida, et. al., In press). The Actiwatch, most importantly, accurately measures when the wearer is asleep. Bosley et al.'s early testing showed that the devices are accurate and reasonably durable. They are also acceptable to the user, and capable of collecting extensive "real-world" data.

Figure 1: Mini-Logger and Actiwatch

The work by Dr. Bosley and his colleagues also demonstrated the many logistical challenges of collected such data in the operational maintenance environment. Example data collection challenges are listed in Table 1. These challenges reinforce the adage that "the devil is in the details."

Table 1: Sample Logistics Challenges for Fatigue and Environmental Data Collection
• **Seeking volunteers** • Scheduling volunteers matched to equipment set-up • Distributing equipment to optimize sampling • Providing 24/7 customer service • Working around vacation and sick time of volunteers • Distributing and collecting equipment with swing shifts • Delivering instruction on equipment care and use • Distributing replacement batteries • Providing private feedback data to volunteer participants

Dr. Bosley and colleagues finished the report with the recommendation that the data collection should continue. While this project focuses on fatigue and environmental factors, other FAA Aviation Maintenance and Inspection Human Factors research efforts are collecting and studying error data. Ultimately, the data related to fatigue and workplace conditions shall be correlated with data related to error.

2.0 PHASE 2 DATA COLLECTION

Phase 1 showed that the data collection tools were dependable and accurate. Phase 1 also demonstrated that the industry is willing and able to participate in the study of fatigue and working condition measurement. The companies and the labor unions were very positive about collecting this data. This second phase, therefore, established the goal to collect a large amount of diverse data. Phase 1 activity collected the data in a very temperate climate, mostly with fixed indoor work. For that reason the current phase of the work sought to collect hot weather data. The team focused data collection on airlines in the Southeast and the Southwest from early July through September. The team sought the jobs that were in the environment including line maintenance, unscheduled nighttime repairs on the ramp, and heavy maintenance in large hangars. For this phase of the study the team did not collect data in the small component repair shops or climate-controlled areas like the engine shops.

The hardware data collection was supplemented with a questionnaire that included not only those who wore equipment but also numerous other volunteers throughout the maintenance organization. The questionnaire was developed and used by Dr. Bosley and colleagues in Phase 1. This questionnaire was designed to understand selected data associated with personal life like exercise, eating, sleeping, perceived job satisfaction and other such factors. Bosley rightfully emphasized that fatigue is often affected by much more than sleep or environmental conditions. The questionnaire helps the research to understand the nature and magnitude of these other personal factors.

Another short questionnaire was used when the hardware equipment was collected, merely to obtain suggestions for subsequent use of the equipment for such data collection.

Table 2 shows the timetable, location, number of shifts and number of volunteers that participated in this extensive data collection phase. The Houston data represents two locations of one company. When appropriate, the data is reported to represent 4 locations. At other times, the Houston data was collapsed to represent one company.

Table 2: Data Collection Timetable, Location, and Participants

Dates	Location	Shifts	Participants	Questionnaires
June	**Atlanta**	4	24	71
July	Dallas	3	22	70
August	Houston	3	21	27
September	Houston	2	23	331

Figure 2 and Table 2 also further describe the participants in the study. Figure 2 shows the distribution of job responsibility between “Line” and “Hangar” and by shift. Figure 3 represents the shift distribution, collapsed across all companies and all locations.

The “Swing-10Hr.” refers to a swing shift that works 4 10-hour days each week. The participants from that shift represent a very small sample (n = 4). Thus, a statistical analysis of that group was usually not of value and was not represented in most of the data within this report.

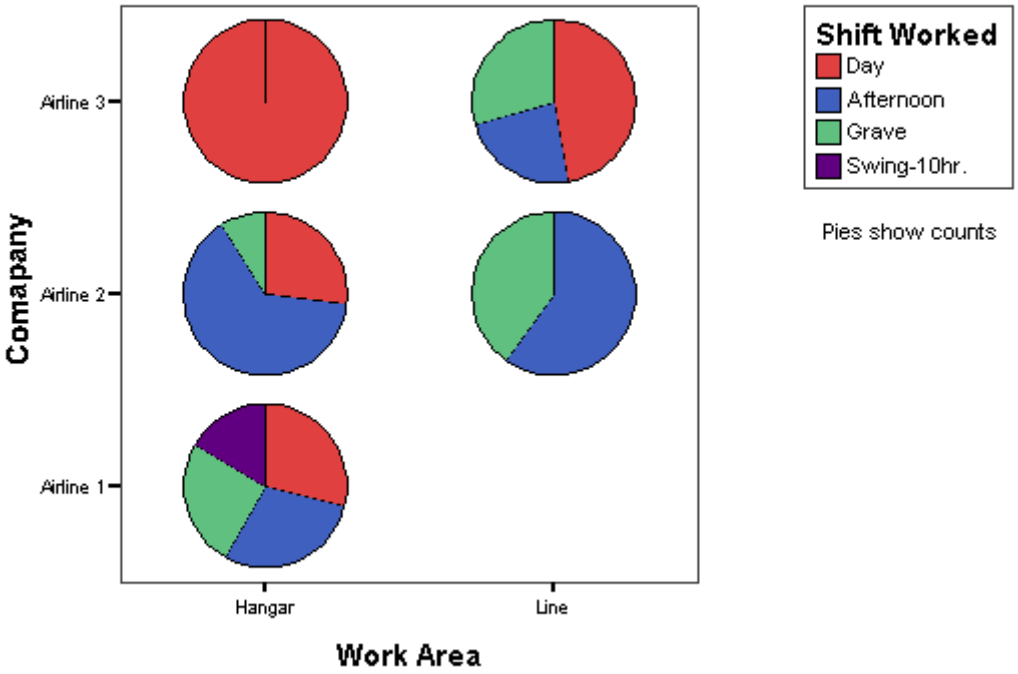

Figure 2: Participants by Job Responsibility and Shift

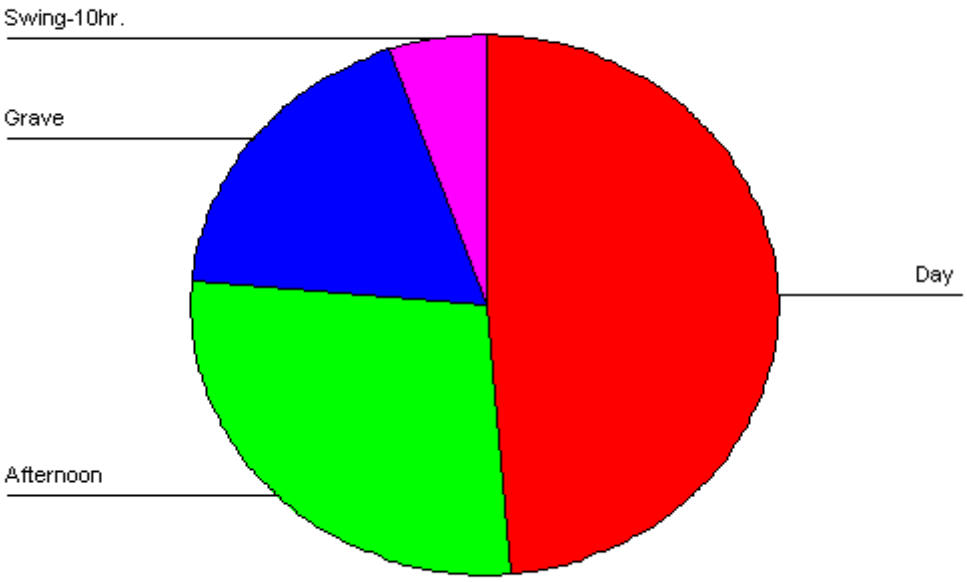

Figure 3: Representation of all shifts across all companies

2.1 Demographics

Males (97.5%) dominated the field study as well as the questionnaire. This number is representative of the aviation maintenance population, as represented by the 500 questionnaires, which were 97.4% males. The participants were predominately line and hangar personnel. The research team asked for volunteers who were engaging in "hands-on" work as compared to predominately supervisory/management tasks.

The average age of the participants was 39 years. The group ranged in age from 25 to 65, thus comprising an excellent sample of the total population of aviation maintenance workers.

3.0 DATA ANALYSIS AND RESULTS

Data reporting, throughout this report, shall be done in a manner in which the identity of the company or any individual cannot be determined. Perhaps the most important finding in this large data collection effort is the fact that the airlines were, in almost all cases, statistically identical, reported at the $p<.05$ level. This is important because the data permit us to characterize working conditions and rest patterns as "industry-representative" rather than as specific to a location or to an airline. The research did show some statistically significant differences between shifts, some age groups, and other factors that shall be reported.

3.1 Sleep Data

Actiwatches measure activity using an accurate accelerometer designed for long term monitoring of motor activity. It measures any motion, sensitive to a force of 0.01 g. The Actiwatch maker offers a number of additional measures, like sleep latency (how fast one falls asleep), sleep efficiency (sleep quality based on interrupted sleep), and other movement-related activity measures.

The two sleep periods of interest are the actual sleep and the assumed sleep. The Actiwatch software calculates the "Actual Sleep". This is based on measurement of inactivity of the wearer and is the very best measure of actual sleep. "Assumed sleep" is nearly equivalent to time in bed. It is based on a number of possible measures. The wearer can press an electronic marker, located on the watch, when they go to bed and when they wake up. Another method is to keep a written sleep log. A third method, the one used in this study, is for the researcher to study each Actiwatch chart and mark the period where relative inactivity commences (to bed) and activity resumes (up from bed). For this study, the researcher confirmed these assumed sleep markers with the participants. The data reported here is "Actual Sleep." The Actiwatch consistently measures it and, thus, it is the most reliable data available. The "Assumed Sleep" was, on the average, about 50 minutes higher than the "Actual Sleep."

Figure 4 shows the nature of the data collected by the Actiwatch. This figure is not meant to necessarily convey data for this report. Instead, the figure shows the detail of the Actiwatch information. For analysis the Actiwatch data is converted from the lines shown in Figure 4 to the SPSS data format.

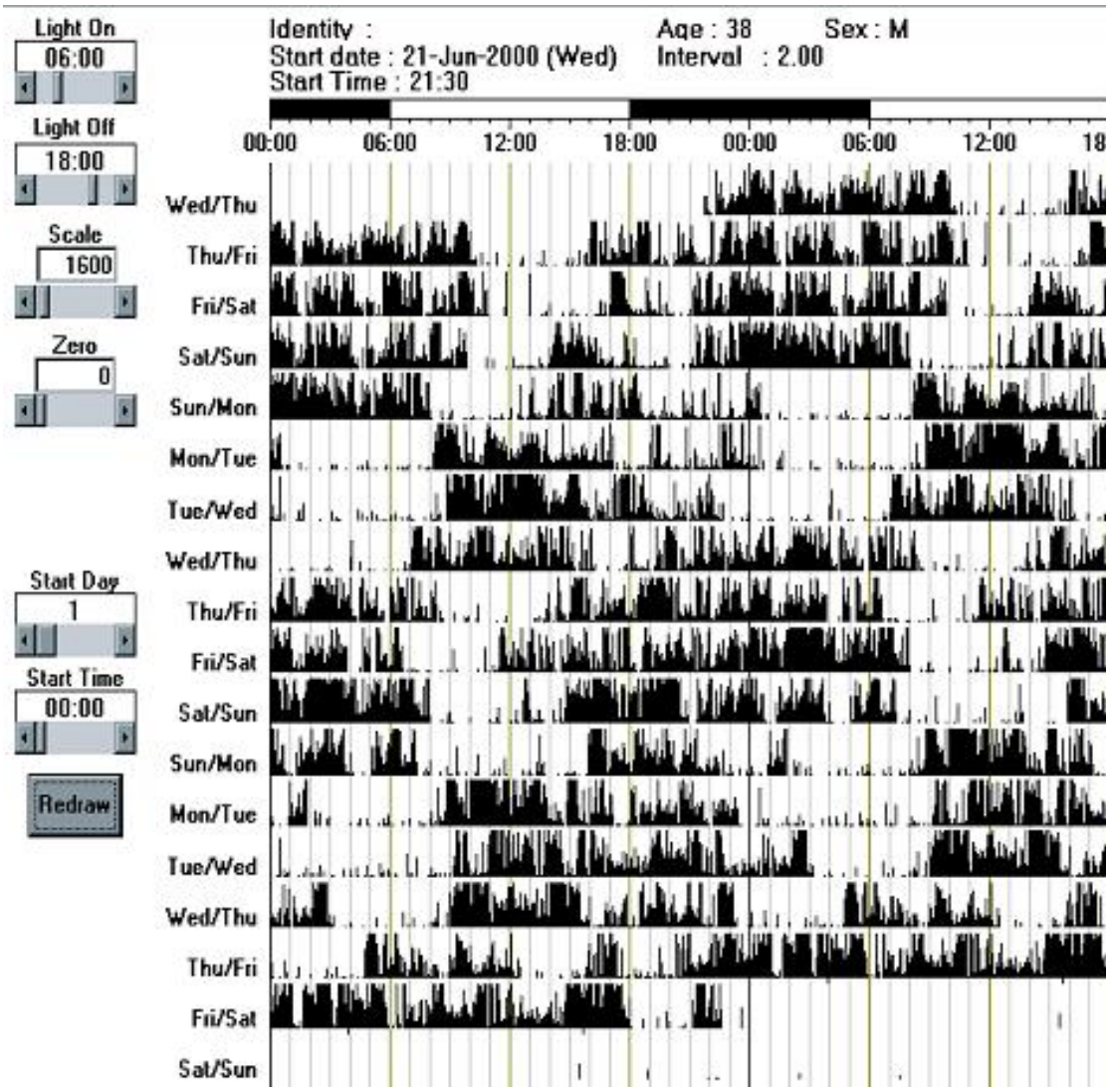

Figure 4: Chart Showing the Sensitivity of Actiwatch Data

Table 3 shows the sleep descriptive data. The airlines are statistically identical with respect to sleep duration. The average sleep for aviation maintenance personnel is 5 hours. There was no significant sleep difference based on age groups. Table 3 shows descriptive sleep data across all shifts represented in this study.

Table 3: Summary of Sleep Data

Shift	N(Number)	Minimum	Maximum	Mean
Day	**30**	**3:24**	**6:38**	**5:06**
Afternoon	**19**	**2:40***	**6:31**	**5:04**
Grave	**12**	**4:01**	**6:09**	**5:00**
All	65	2:40	7:36	5:05

*Confirmed with participant when analyzing sleep data on outbreifing

3.2 Temperature Data

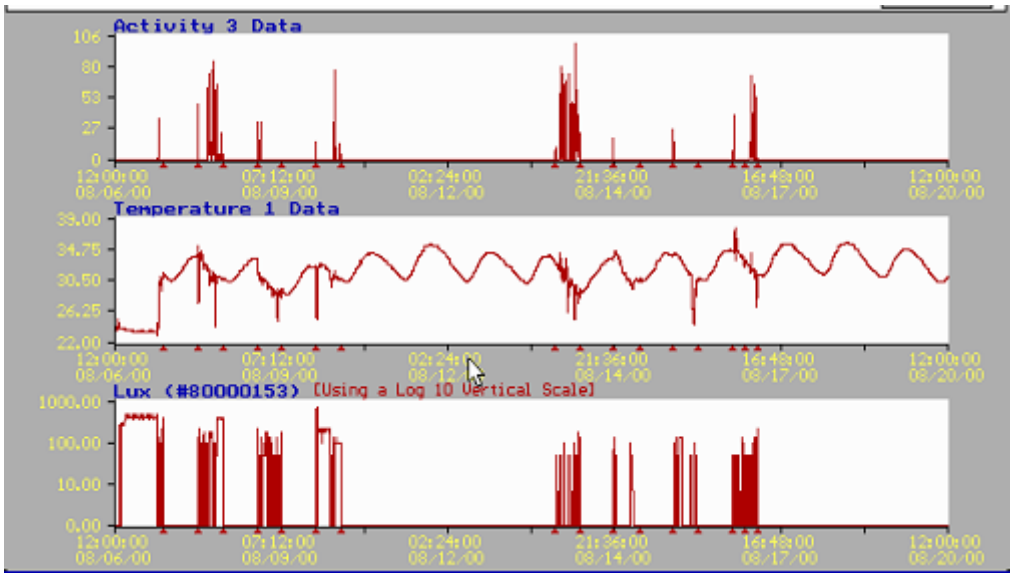

Figure 5: Sample Mini-Logger Data for Temperature, Light, and Sound

The Mini-Logger collected Temperature, Sound Pressure, and Light data. Figure 5 shows a sample of the Mini-Logger output. This data is shown, not to convey specific information, but to show the nature and sensitivity of data. The equipment records an average reading every two minutes, thus the amount of data can be overwhelming. Data was transferred from the Mini-Logger to the SPSS program for analysis.

This was a warm weather study conducted in the Southeast and Southwest during the summer. The highest recorded temperature during the study was 130F (54°C+). That is not surprising since the US National Weather Service reported temperatures in Texas during the data collection period in excess of 110F (43C+). Table 4 shows temperature distribution by location by shift. Appendix A includes a listing of temperature and humidity by location and date.

Table 4: Temperature Ranges by Shift and Work Area

Temperature Data	N	Mean °F – °C	Standard Deviation °F – °C
Overall	49	86 - 30	4.9 – 2.7
Hangar	37	86 - 30	5.3 – 2.9
Line	12	84 - 29	3.2 – 1.8
Day	22	87 - 31	6.5 – 3.6
Afternoon	15	86 - 30	2.9 – 1.6
Grave	12	84 - 29	2.4 – 1.3

3.3 Sound Pressure Data

Sound, measured in Decibels (dBA), was statistically the same across all airlines. The average level was 67 dBA. As one might expect, there is significantly less noise on the Graveyard shift with an average dBA level of 59 across the carriers. Additional analysis indicated that about two thirds of the sound readings were between 41 dBA and 93 dBA. Table 5 depicts the sound data by shift and work area. The afternoon shift experienced the highest sound levels, but there was no statistical or practical difference between day and afternoon.

Table 5: Sound Data by Shift and Work Area

Sound Data (dBA)	N	Mean	Median
Overall	52	67.7	76.4
Hangar	37	68.8	76.6
Line	15	64.9	74.8
Day Shift	25	67.7	74.5
Afternoon Shift	15	73.2	80.5
Grave Shift	12	60.8	71.2

3.4 Light Level Data

The light data was measured in lumens per square meter, called a lx (lx). The sensor emerges from the Mini-Logger with the light-sensing probe emerging from the front pocket of the maintenance participant. The light measure, therefore, is the amount of light (illumination) on the person rather than the amount of light on the work. In most cases the measurement on the work or on the person is similar. However, in reduced light situations, when a flashlight or other directed light is used the measurement may be misleading. There are also times, in full ambient light, when the maintenance worker must look inside of a cowling or other such area where light is greatly reduced. The Mini-Logger does not account for that situation. For that reason, these data are more powerful when they are combined with responses from the questionnaire, reported in Section 3.5.

The light data is a statistician's delight and a nightmare for someone looking for a straightforward answer. There are data ranging from total darkness to blinding sunlight. The authors made the decision to search for the most straightforward explanation with the ability to make accurate recommendations to the industry. The data reported here are aligned with the data reported by Dr. Bosley (1999) and Thackray (1993).

Table 6 shows the industry average light and the median light (the reading in the very middle of all the data). The table shows the break out by number of participants (n), shift, and work area. Overall, there was a considerable range, most of which is below recommendation as discussed in Section 3.5.2.2. In this sample the afternoon shift's light readings were higher than the day shift. This may be attributable to the fact that there were more "line" data collected on the afternoon shift than the other shifts. Additionally, the daylight hours during the summer extend during most of the afternoon shift.

Table 6: Light Data Across Shifts and Work Areas

Light Data (lx)	N	Mean	Median

Overall	53	692	266
Hangar	38	578	156
Line	15	979	783
Day Shift	26	649	236
Afternoon Shift	15	1182	758
Grave Shift	12	172	103

3.5 Questionnaire Data

The research team distributed a 41-item questionnaire to maintenance personnel at four different airports around the southern United States. A total of 499 personnel completed and returned the questionnaires. The items on the questionnaire served to gather basic demographic information, information about personal habits and information about fatigue and alertness in the workplace. The questionnaire was successful in obtaining a broad and diverse cross section of airline maintenance personnel. A complete summary of the results can be found in Appendix B.

Personnel were selected in a non-random fashion to complete the questionnaire. As such, the results of the questionnaire may not be completely representative of aviation maintenance workers in general. However, the questionnaire does provide excellent insight into how maintenance workers feel about fatigue and alertness issues. Copies of the questionnaire were distributed to the participating airlines that then distributed the questionnaires to maintenance workers. Participation in this research was voluntary.

This section (3.5 and subsections) is reported slightly differently than sections 3.1-3.4. Within this section the authors discuss the results of the questionnaire. The reason for this minor style difference is that the nature of the questionnaire data and charts are more conducive to immediate discussion. The additional reason is to ease the logistics of reading and interpreting the data as it is presented.

3.5.1 Demographics

3.5.1.1 Roles

The questionnaire was distributed to maintenance personnel serving in a variety of roles. Figure 6 shows the proportion of respondents who worked in each of 11 maintenance areas. As Figure 6 shows, many of the respondents (46.1%) work in the “Airframe” capacity.

3.5.1.2 Age

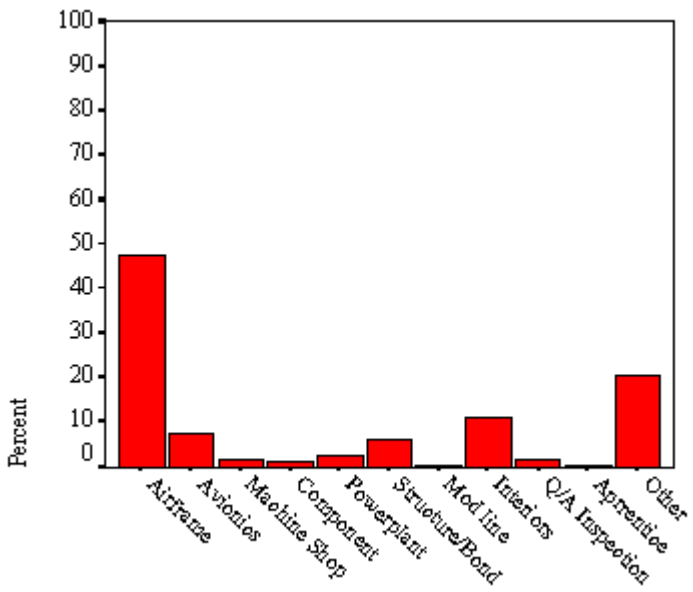

Figure 6. Percentage of Respondents Serving in Various Positions

Figure 7 depicts the proportion of respondents that fell into each of 6 age groups. As can be seen, a substantial portion of respondents (41.7%) fell in the 36 – 45 year old age bracket. The 26 – 35 year old bracket was second in size, capturing 29.7% of the respondents. There were very few respondents fewer than 25 years old or over 66 years old, with each of those brackets containing 2.6% and .4% of the respondents, respectively.

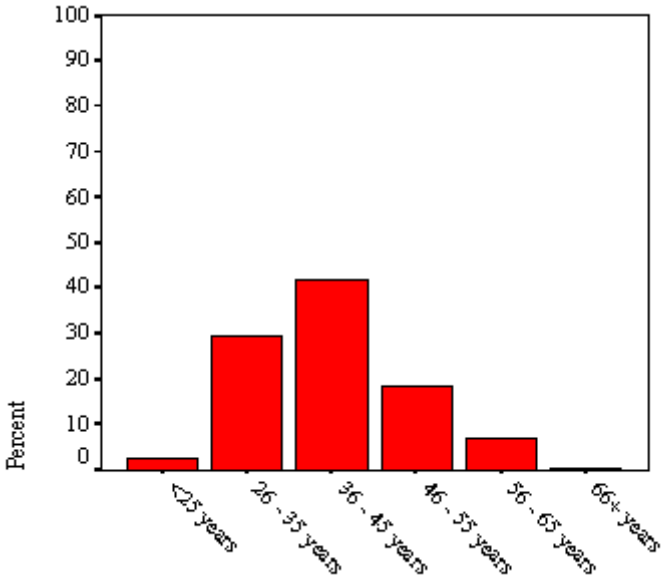

Figure 7. Proportion of Participants Across Age Brackets

3.5.1.3 Job Experience

The questionnaire collected information about how long each participant has worked as a mechanic or AMT. Results indicate that members of the sample have a wide range of time on the job, with the bulk of the participants (37.7%) having between 10 and 14 years of experience. Individuals with less than 5 years of experience and with over 20 years of experience are also well represented in the sample (see Figure 8).

3.5.1.4 Shift Work

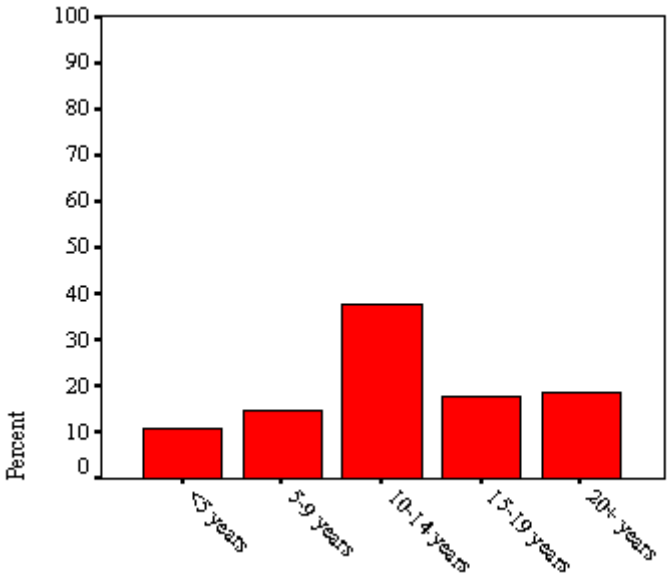

Figure 8. Experience of Participants Working as Mechanic/AMT

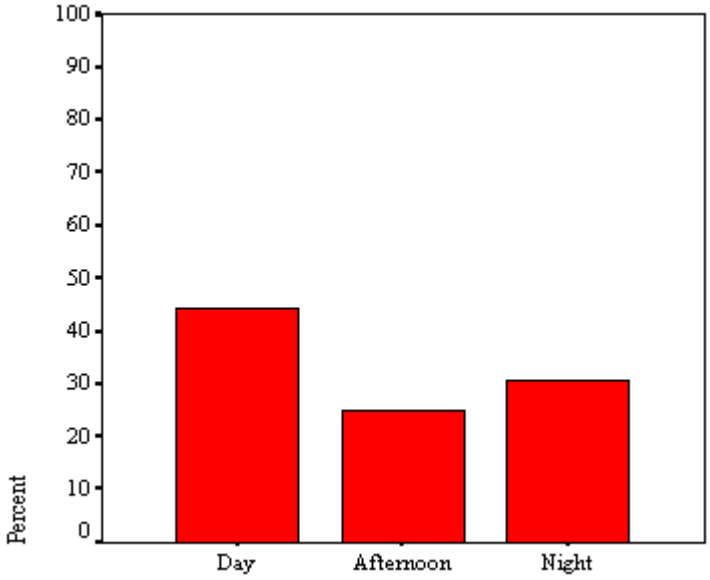

Figure 9. Proportion of Participants Working Each Shift

Maintenance personnel at most facilities worked one of three shifts: Day, afternoon, or night (also called graveyard). Personnel were asked to indicate which shift they were currently working, as shift changes are often made on a periodic basis. As can be seen in Figure 9, all three shifts are represented in the sample with the bulk of participants (43%) working the day shift.

3.5.2 Sleep, Fatigue/Alertness, and Lighting

The questionnaire collected a considerable amount of information from each of the participants, including information about eating habits and feelings about work. The discussion in this report

shall focus primarily on fatigue and alertness issues. In total, six separate items addressed the issues of sleep and fatigue/alertness on the job (items 8, 21, 33, 36, 40, and 41). Two other items (25 and 30), addressing lighting adequacy, may be indirectly related to fatigue and alertness (Human Factors Guide, 1998). The data were examined across age group and shift worked to determine if response patterns differed systematically as a function of these grouping variables. Analyses indicated that the shift-work grouping variable was related to response patterns on questions concerning fatigue (see section 3.5.3). Results from the survey are presented in the following several sections. Figures 10 through 14 depict participants' responses to questions about sleep and fatigue/alertness, and Figures 15 and 16 relate to participants' opinions regarding the adequacy of work place lighting. Figures 17 through 20 break the fatigue/alertness item responses apart by the shift-work grouping variable.

3.5.2.1 Sleep and Fatigue/Alertness

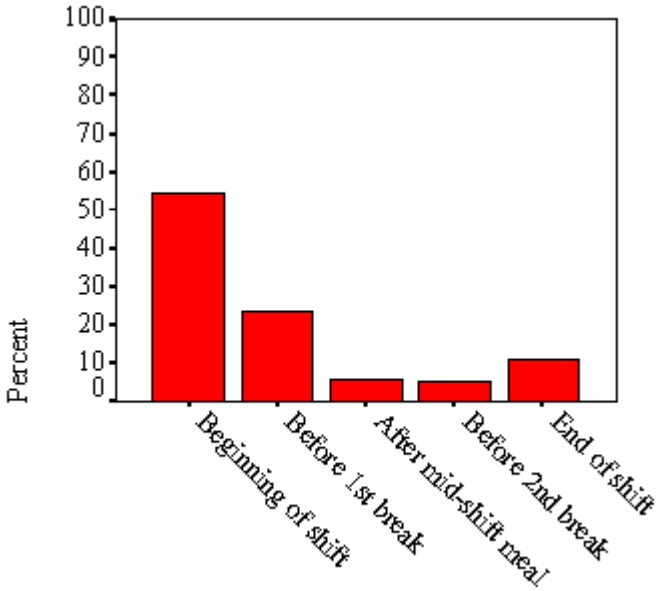

Figure 10. Period of Shift When Participants Feel Most Alert

For the most part, the response patterns to these items are rather predictable. For example, Figure 10 shows that most of the respondents indicated that they feel most alert at the beginning of their work shift (Item 8), and Figure 11 shows that most "sometimes" feel fatigued at work (Item 21). About 30% of participants indicated that fatigue is a factor that negatively impacts their job performance (see Figure 12; Item 33). Figure 13 shows a relatively normal distribution regarding the amount of sleep obtained during the previous night (Item 36). Figure 13 seems to be unaligned with the actual sleep data collected with the Actiwatches.

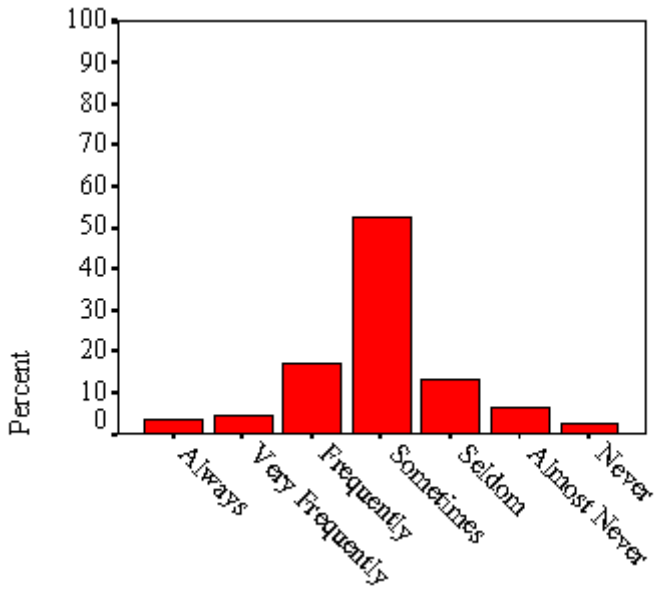

Figure 11. Participant Indications of How Often They Feel Fatigued at Work

Figure 13 shows that over 60% of the respondents reported that they slept over 6 hours the previous night. However, the Actiwatch data shows accurately that the average sleep was about 5 hours. The Actiwatch data also indicates that about 67% of the participants slept on average between 4.2 and 6 hours. This difference in data, between Actiwatch and self-report, may be attributable to numerous factors. First, the respondents may be over reporting their sleep slightly. Secondly, the Actiwatch is very accurate and does not count the initial "tossing and turning" as sleep. Thus there is a likely difference between the time in bed versus the actual sleep time. In any case, the combination of the Actiwatch data with this questionnaire and with the previous fatigue questionnaire (Sian and Watson, 1998) strongly suggests that maintenance personnel are not fully aware of their sleep duration and the possible fatigue that may result.

Another study, conducted by the Gallup Organization (Gallup, 1997), polled "the public" to determine how many hours of sleep they need to feel alert. The public average was 7.2 hours with 67% grouped between 6.0 hours and 8.4 hours. Obviously, this represents more sleep than the aviation maintenance questionnaire respondents indicated and much more than the Actiwatches measured.

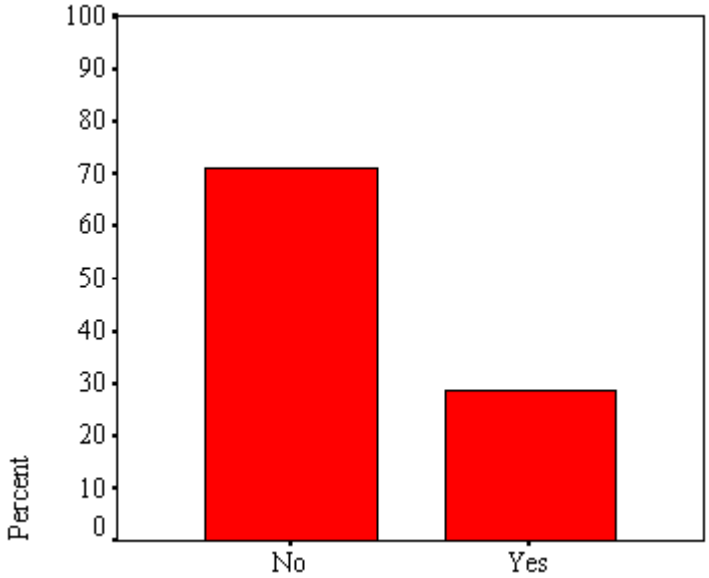

Figure 12. Percent of Participants Indicating that Fatigue Negatively Impacts Their Work Performance

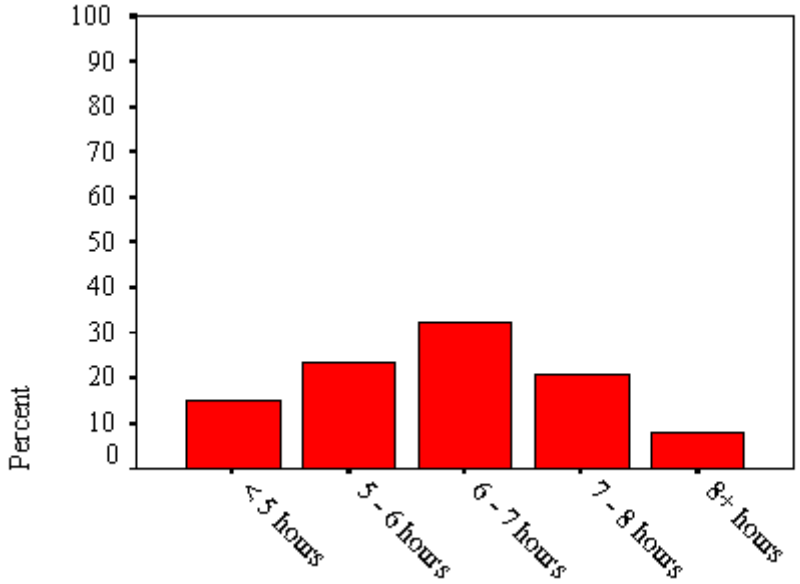

Figure 13. Participant Indications of Hours of Sleep the Previous Night

The questionnaire also measured perceived levels of fatigue for the beginning of a shift and the end of a shift and Figure 14 illustrates that participants did not perceive their alertness to change from the beginning of a shift to the end of a shift (Items 40 and 41). The collective set of these data and figures suggests that the airline maintenance workers do not perceive fatigue as a major problem. This is consistent with other questionnaire findings (Sian and Watson , 1998).

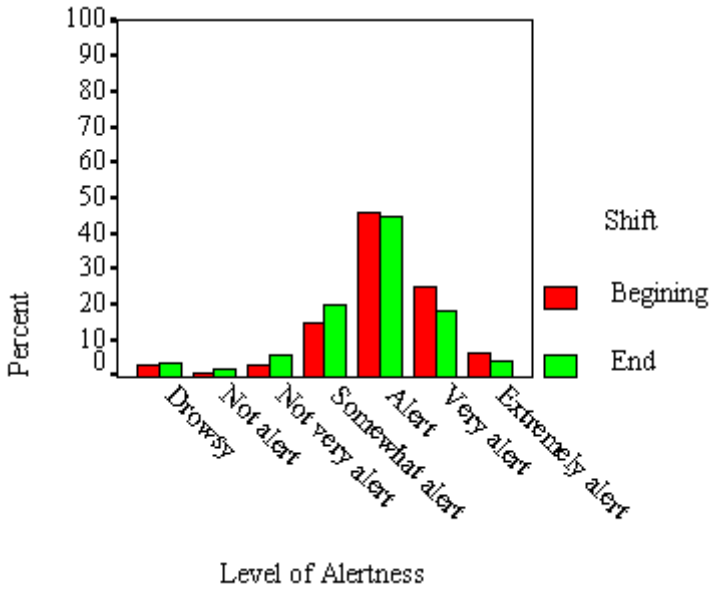

Figure 14. Participant Indications of Alertness Level at the Beginning and the End of a Shift

3.5.2.2 Adequacy of Lighting

Items 25 and 30 on the questionnaire addressed the issue of adequate lighting. Questionnaire responses indicated that about 45% of participants work under inadequate illuminated conditions

"Frequently" or more often (see Figure 15), and that over 40% of participants felt that inadequate lighting negatively impacted their job performance (see Figure 16). This data is in agreement with the data from the Mini-Logger. In this case the questionnaire data is likely to be more accurate than the Mini-Logger measurements, because it is based on the actual perception of the workers.

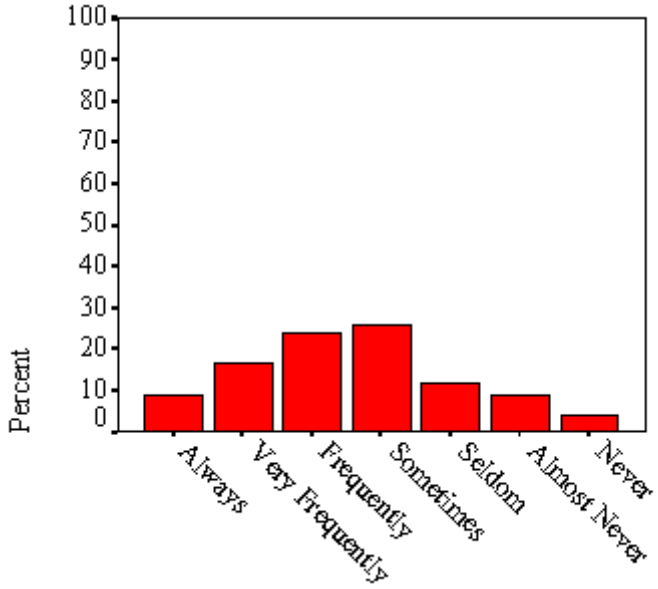

Figure 15. Participant Indications of How Often They Work With Inadequate Lighting

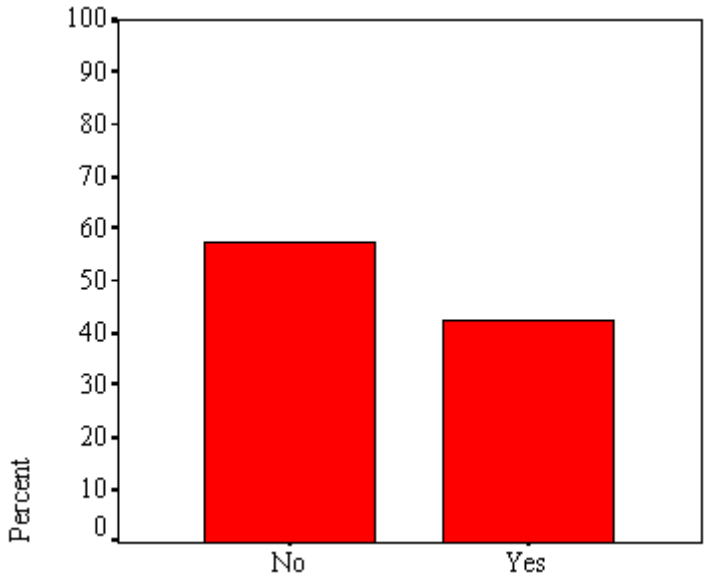

Figure 16. Proportion of Participants Indicating That Inadequate Lighting Negatively Impacts Job Performance

In summary, many participants feel that lighting conditions are less than optimal for a substantial portion of the time that they are working. Furthermore, a substantial number of participants felt that poor lighting does have a negative impact on their job performance. Due to the way in which this questionnaire item was phrased, it is impossible to know *how* inadequate lighting negatively impacts performance (i.e. reduction of quality, reduction of quantity, etc.), only that many participants *perceive* a negative impact. But this information can be very telling as the participants are experts at

what they do and the data indicate that lighting is not adequate in many circumstances and that this causes problems on the job.

3.5.3 The Impact of Shift Work on Fatigue and Alertness

Examination of the data at an overall level does not address the possibility that other factors, such as shift worked, are related to the responses. Shift work is related with job performance and fatigue (Tepas, 1991). Therefore, the data from questionnaire items 8, 21, 33, 40, and 41 were broken apart by shift worked.

Questionnaire item 8 asked participants to indicate the period in their shift when they feel most alert. When all responses are considered, the majority of participants indicated that they feel most alert at the beginning of their shifts, but when the responses are broken apart by the shift worked, it appears that some of the day shift participants may take a little longer to "wake up" than the afternoon and evening shift participants. This is illustrated in Figure 17 with a smaller percentage of day shift participants indicating that they are most alert at the beginning of their shift relative to the afternoon and evening shift participants. Response patterns are similar for the remaining data points.

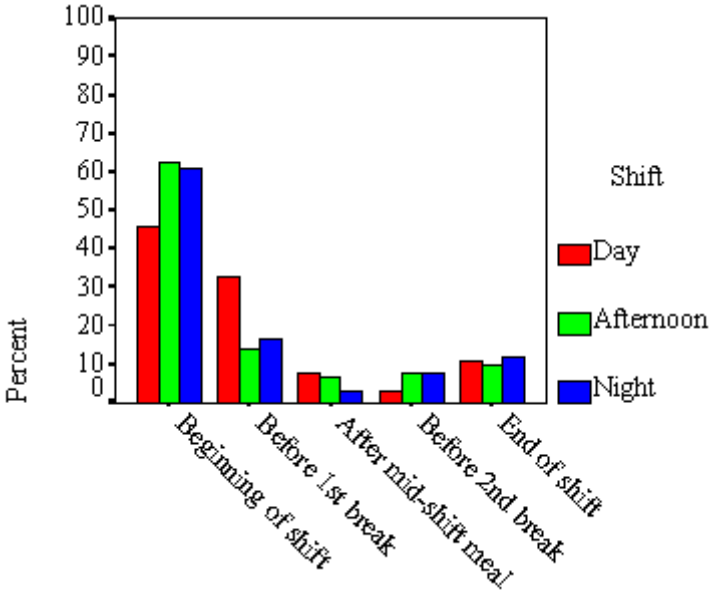

Figure 17. Period of Shift When Participants Feel Most Alert by Shift

Item 21 on the questionnaire collected information about how often participants feel tired or fatigued at work. As can be seen in Figure 18, there is a larger percentage of night shift participants who indicate that they are "Frequently", "Very Frequently", or "Always" fatigued at work (35.3%) relative to the day and afternoon shift participants (23.9% and 16.6%, respectively). This data suggest that shift work is related to fatigue, such that night shift participants are more likely to report being fatigued on the job relative to day and afternoon participants.

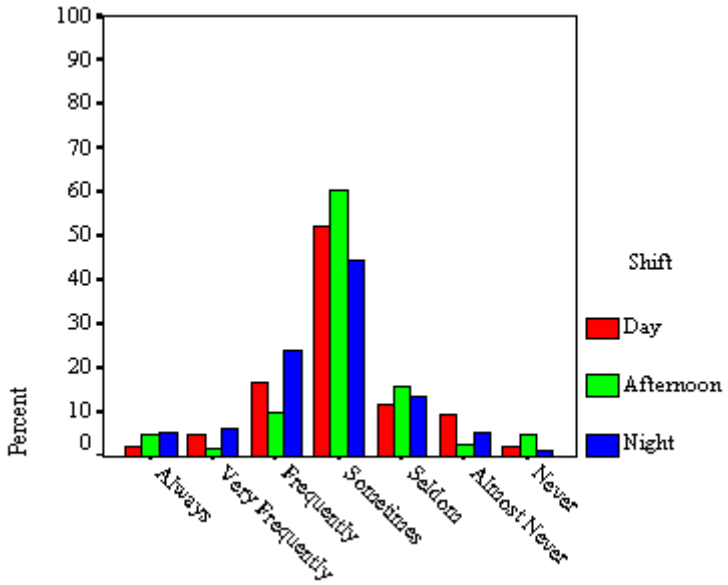

Figure 18. Participant Indications of How Often They Feel Fatigued at Work by Shift

Item 33 on the questionnaire asked participants to indicate which of several factors had a negative impact on job performance. One of the factors listed in the item was fatigue. Overall, almost 30% of the participants indicated that they felt fatigue had a negative impact on their performance. When the responses to this item are broken apart by shift, over 40% of the night shift participants indicated that fatigue negatively impacted their performance relative to about 25% and 19% of the day and afternoon shift participants, respectively. While the wording of item 33 makes a direct interpretation of its responses difficult, it is clear that the night shift participants have a different perspective about fatigue in comparison to the day and afternoon shift participants. This indicates that fatigue is perceived to be more of a problem by night shift participants than by day and afternoon shift participants.

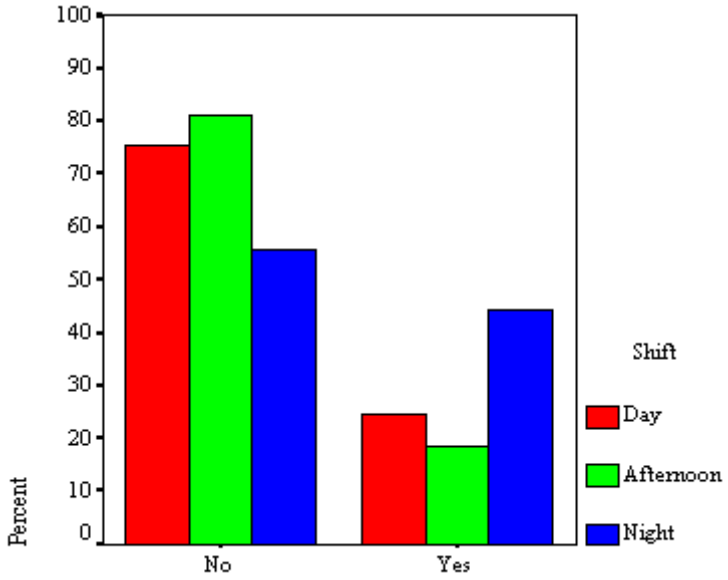

Figure 19. Percent of Participants Indicating that Fatigue Negatively Impacts Their Work Performance by Shift

Items 40 and 41 on the questionnaire asked participants to rate their level of alertness at the start and end of their shift. There were seven possible responses ranging from “Drowsy” to “Extremely Alert”.

Figure 20 shows the mean ratings of alertness for each of the three shifts at the beginning (item 40) and end of the shift (item 41), where "Drowsy" is given a value of 1 and "Extremely Alert" is given a value of 7. Figure 20 shows that levels of reported alertness stay relatively steady from the beginning to the end of the shift for the day and afternoon shift participants. However, the night shift participants show a statistically significant decrease in reported alertness from the beginning of the shift to the end of the shift. Furthermore, the average reported level of alertness by the night shift group for the end of the shift is lower than that reported by the day and afternoon shift groups. While it is difficult to determine the practical significance of this difference, it is more evidence that participant perceptions of alertness vary as a function of the shift worked by the participant. In other words, shift work and alertness are related, as are shift work and fatigue (see also Figures 18 and 19).

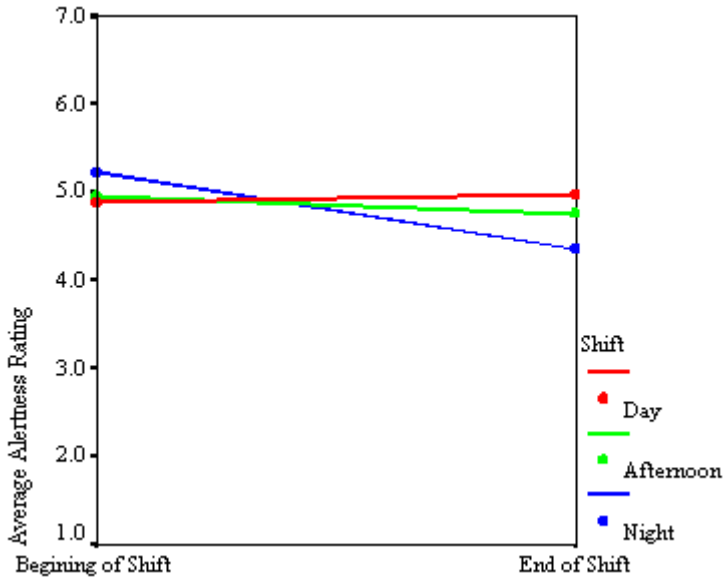

Figure 20. Average Alertness Ratings at the Beginning and End of a Shift for Each Group of Shift Participants

These data regarding the impact of shift work on perceived fatigue are consistent with the literature (Tepas, 1991) and are therefore not surprising. While other factors, such as environmental factors, may have an impact on fatigue and alertness, these data present evidence that working the night shift is linked with higher levels of fatigue, lower levels of alertness, and reduced levels of perceived job performance.

4.0 RECOMMENDATIONS

This section shall emphasize the areas where the observed data are outside of the recommended limits. Phase 3 of this research program shall contain extensive information to mitigate fatigue, lighting, sound, and temperature extremes.

4.1 Sleep

Table 7 shows summary Actiwatch data and the recommendations for sleep. Most researchers advocate an average sleep requirement for adults is 7.5-8.0 hours per day.

Table 7: Actual Sleep vs. Recommended Sleep	
Mean Overall Sleep Experienced by Participants	**Recommended Levels by Carskadon & Dement as cited by Battelle, 1998**

Mean: 5:06 sleep per night* *Assumed sleep was nearly 6 hours.	7:30 to 8:00 sleep per night

The data clearly shows that airline maintenance personnel sleep about 5 hours per day. All sleep experts agree that 5 hours is not enough sleep (Battelle, 1998). The experts would argue that the population of maintenance personnel is acquiring a daily "sleep debt" of at least 2 hours. Since the Actiwatch was worn 7 days a week for the two-week data collection period it does not appear that maintenance personnel are repaying the sleep debt. However, the questionnaire data reported in Section 3.1 does not reflect a population that perceives chronic fatigue or tiredness. The data collected from the Actiwatch strongly suggests that the population of aviation maintenance workers has a sleep deficiency problem and has not yet acknowledged that potential problem. The only caution that must be added here is that "Assumed Sleep" as discussed in Section 3.1 is about 50 minutes greater than the actual measured sleep. In either case, the sleep amount is below recommendations.

Changing the culture of aviation maintenance personnel to sleep more hours is likely to be difficult. Education may be the only way to accomplish this cultural change. During the data collection the research team observed that the personnel who wore the Actiwatch became sensitized to their sleep habits. It is likely that airline maintenance personnel are simply unaware of their sleep habits versus the recommended sleep amounts. Airlines could use equipment like Actiwatches to help technicians to understand their sleep habits and form improved habits if necessary. While this is only speculation, the productivity return on investment would quickly justify the cost of the equipment, administration personnel, and training. Phase 3 of this research program shall try to determine the extent of error and associated cost can be based on worker fatigue.

Another possible manner to motivate personnel, with respect to sleep, is to initiate an education campaign related to "Fitness for Duty." While many associate "Fitness for Duty" with alcohol or drugs it can also apply to sleep. Of course, sleep deprivation is not as easy to measure as alcohol or drugs.

Instead of changing the culture regarding sleep another approach is to make personnel aware of the signs of fatigue. If personnel can recognize fatigue they can help one another to avoid the inevitable performance degradation and potential error. During 2000, the Air Transport Association 9 (ATA, 2000) published the *Alertness Management Guide*. The document was designed for flight crews but has applicability to everyone. The ATA guide offers quick explanations of the importance of sleep as a vital physical need. It strongly endorses the importance of the 8-hour sleep requirement and the "debt" that accumulates. Among the many recommendations offered are such actions as the following: Minimize sleep loss; alter habits to acquire necessary sleep; create the right environment for sleep and; the effect of age, alcohol, diet, and exercise on sleep. This type of guideline and education program should be implemented for maintenance personnel. The labor unions, companies, or the FAA through this research program should foster such informational activity.

4.2 Temperature

Table 8 shows summary Mini-Logger data and the recommendations for temperature. The summer temperatures in the Southeastern and Southwestern United States are quite high and certainly affect work performance and promote fatigue. The saying goes "that you don't need a weather man to know which way the wind blows." That expression applies here with respect to the Mini-Logger temperature probes to know that it is hot. Sixty-nine percent of the questionnaire respondents said that high temperatures affect their job performance. That was rated higher than any other factor. The temperatures reported here have not factored in the high humidity levels. The danger is that high temperature tells only a portion of the story.

Table 8: Actual Temperature vs. Recommended Temperature	
Mean Overall Temperature Experienced by Participants	**Recommended Levels by FAA Human Factors Guide for Aviation Maintenance**
86°F (35°C)	**Thermal Comfort Index Chart must be used, See Figure 21**

Figure 21 shows a "Comfort Zone" chart (Human Factors Guide, 1998). This table was used to discuss temperature at one of the mechanics' meetings at a Texas airline. It was duly noted that seldom was there a time of the day or the night when the work was inside the envelope of the "Comfort Zone." Most of the time (See Appendix A) during the summer study, in June-August, the humidity was quite high. According to the national Weather bureau that would rate the working conditions in a Level III category classified as "Hot" (Steadman, 1979). This merely amplifies the importance of hydration, rest, portable cooling systems, proper scheduling, and more to mitigate the high temperature high humidity working environment.

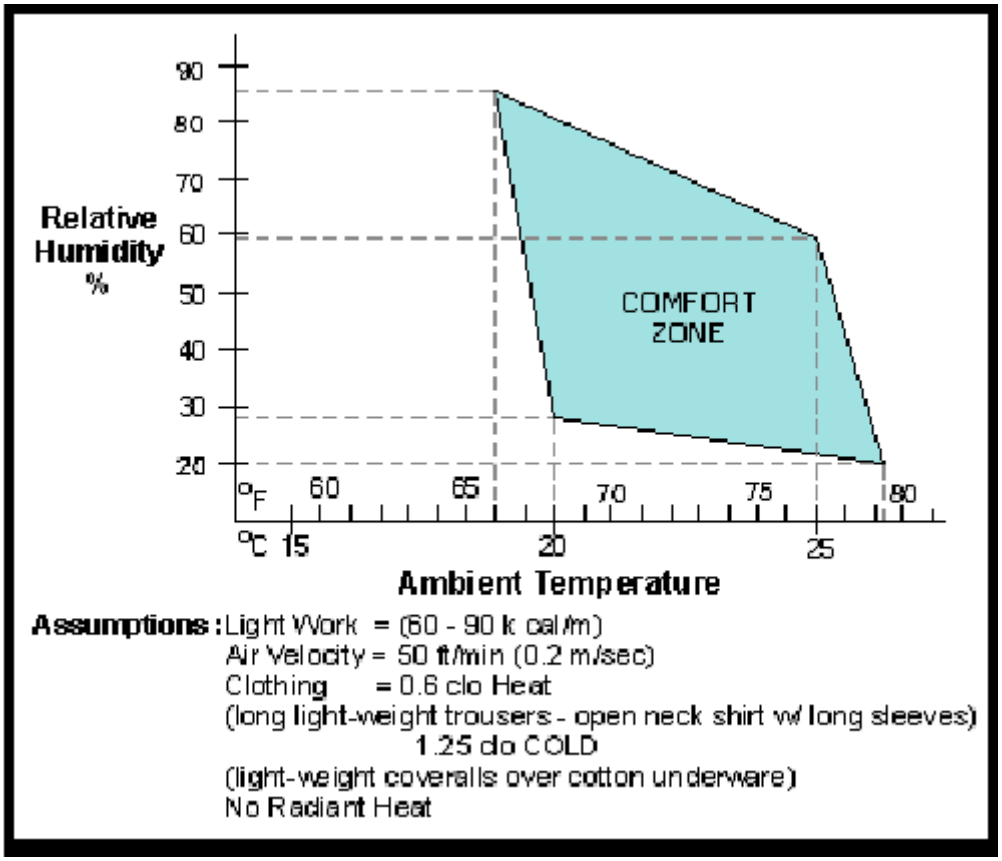

Figure 21: Thermal Comfort Index from Human Factors Guide

The companies that participated in the study followed most of the good practices related to working in high temperature conditions. Water and ice must be, and were, quite plentiful. In all cases there were water jugs, ice, and large and clean drinking cups. In most cases the containers were located close to the work areas making it very convenient for works to get a drink of water. The questionnaire data confirm that workers were likely properly hydrated. Ninety-seven percent of the respondents said that water was readily accessible at work. Eighty percent of the respondents had water at least 3 times each day, while 39% reported at least 5 glasses of water each day.

It is valuable to move the air, even when the air is an elevated temperature. Again, the research team

observed numerous portable fans and portable air conditioning systems. For the hangar work all of the aircraft interiors were cooled adequately. The challenges occur when unscheduled maintenance arises and workers must access elevated tail sections, cargo bins, avionics compartments, and similar confined spaces. It is critical that workers maintain a focus not only on the job task but also on the temperature of the work environment.

The extreme high temperatures were observed on the flight line. The combination of high ambient temperatures on the hot ramp with hot aircraft and ground equipment presents a very high temperature risk. The team observed an awareness of this high temperature challenge. The means of mitigating such conditions include adequate staffing, reasonable scheduling of activity, proper pacing in high temperature conditions, plenty of water, and adequate rest throughout the work shift.

4.3 Sound Pressure

The questionnaire data rated "Noise" as the third highest (58%) environmental factor affecting job performance. The temperature and humidity were ranked 1 and 2, respectively. Noise may be even more difficult to control than temperature/humidity. High sound is an unavoidable by-product of turbine engines and industrial repair equipment. However, the industry can and does take steps to be sure that the high sound levels do not injure workers or completely stifle safe and effective communication.

Table 9 shows summary Mini-Logger data and the OSHA recommendations for sound levels. The mean overall sound experienced by most (67%)participants was 67 dBA +/- 26, within the OHSA limits. Since the volunteers wore the Mini-Loggers and Actiwatches without supervision, it is not possible to know when hearing protection was worn thus the sound pressure measurements are nor particularly valuable. Research observations indicate that ramp personnel, in particular, wore hearing protection as required. Future analyses shall assess duration of sound pressure as well as levels.

Table 9 shows that the average observation is well below the OSHA limits for sound levels over time duration. The measured is well below the 85 dBA shown at the bottom of the Table.

Table 9: Recommended Levels by OSHA Noise Standard 1910.95

Mini-Logger Observed Data Average	When Noise Level is:	For a Time Duration of:
67 dBA	105 dBA	1 hr.
NA	100 dBA	2hr.
NA	97 dBA	3 hr.
NA	95 dBA	4 hr.
NA	92 dBA	6 hr.
NA	85 dBA	8 hr.
	Then hearing protection must be worn.	

Recommendations regarding sound and noise control are available in the *Human Factors Guide for Aviation Maintenance*. *The Guide* stresses the importance of determining alternatives for verbal communication in high ambient noise environments. *The Guide* also offers guidance for workplace design to isolate and protect workers from harmful noise.

4.4 Light Level

Forty-two percent of the questionnaire respondents rated inadequate lighting as a factor that affects job performance. That factor was number 4 following temperature, humidity, and noise. Nearly 50% of the respondents indicated that they worked in inadequate lighting "Frequently, Very Frequently, or Always." There appears to be a lighting problem as reported by the respondents.

The light data, from the Mini-Loggers confirmed the opinion of the questionnaire respondents. The overall mean of 692 appears to be on the low side of the recommendation shown in the table. However, as mentioned in Section 3.4, the data had an unusual statistical distribution. The middle (Median) amount of lux was 266, which is considerable below the recommendation. This situation is caused by the fact that the majority of participants had very low average light readings.

The "bottom line" is that the data show that, generally, there is not enough light in the maintenance workplace. Ambient illumination, as measured at the front pocket of the Mini-Logger wearer is insufficient for most maintenance and inspection work. Table 10 shows summary Mini-Logger data and the recommendations for light levels.

Table 10: Actual Light Levels vs. Recommended Light Levels

Mean Overall Light Experienced by Participants	Recommended Levels by FAA Human Factors Guide for Aviation Maintenance
Mean: 692 lx Median: 266 lx	Between 750 – 1000 lx

Numerous Human Factors studies have lamented the inadequate lighting conditions in the airline maintenance environment. The data confirms past studies. The measured data showed that ambient illumination is low and inadequate. The light probes could not account for portable directional lighting systems that are often available. However, the 500 questionnaire respondents, most likely, considered all lighting situations as 40% rated the lighting to be inadequate, as discussed in Section 3.5.2.

When one searches the A Maintenance Human Factors Website on the word "lighting" there are 417 hits. There are 133 hits on "illumination", 43 on "flashlight," and 1 on "torch" for the British readers of this report. The *Human Factors Guide* offers checklists to assess the workplace for proper illumination. The *Guide* also leads to references on lighting such as the *IES lighting handbook-Application volume* (IES, 1987).

4.5 Questionnaire Data

The focus of the present research project has changed somewhat since the questionnaire was initially developed. There is currently less emphasis on personal habits (e.g. exercise and nutrition) and more emphasis on alertness/fatigue and environmental factors. Therefore, the breadth of the questionnaire can be reduced while still collecting important information about fatigue and environmental factors. Questionnaire information can be coupled with the physical data being collected by the Actiwatch and Mini-Logger collection devices to establish a very accurate and complete picture about the environment in which maintenance personnel work in and its relationship to issues of fatigue and alertness. Items which are not intended to measure fatigue, alertness, or related environmental issues have been removed in the latest version of the questionnaire. If issues such as job satisfaction or job stress are of interest, then questionnaires already developed and validated for those purposes will be used.

The research team shall use a new and revised version of this questionnaire for the Year 2001 data collection. The new survey eliminates many non-essential items, making the survey shorter and more "user-friendly". Additionally, many items are revised so that respondents are asked to give whole number data instead of selecting one of several grouped options. For example, instead of having participants indicate which age group they belong to, the participants are asked to write in their actual age. This data format is more flexible and has an advantage over categorical data when statistical analyses are needed for examination purposes.

The revised questionnaire shall assess the impact of environmental factors (i.e. light, temperature, and sound) on alertness and fatigue. It will also assess participants' perceptions of when they feel most alert and the extent to which they obtain sufficient sleep. This will be done using a series of Likert-type items for each of the above-mentioned constructs. The Likert-scale is a widely used questionnaire item format that presents a statement and participants are asked to either agree or disagree with the statement using a 5-, 6-, or 7-point scale. Several items (usually 4 or more) are written to assess opinions regarding a single construct. Several of the items within each scale are "reversed" in order to reduce the tendency of some participants to respond to items either favorably or unfavorably without reading the item first. Responses to items measuring the same construct are averaged across participants and can then be used in a variety of statistical analyses. For example, items can be compared across groups to determine if the different groups of participants, night shift versus day shift for example, responds differently to the items. They can also be used in other statistical procedures such as correlation in order to determine if different constructs are related to one another. These are properties that categorical response items do not have and as such, have less utility than Likert-type items.

Questionnaires can and should play an important role in investigating the issues of fatigue and alertness as they relate to other factors such as lighting, shift worked, and type of job. Questionnaires, as compared to the Actiwatch and Mini-Logger data collection systems, are much more practical, can be distributed to a larger number of people, and are less expensive. Unfortunately, questionnaire data tends to be less accurate and precise than standardized physical measures. The information collected with a well-developed questionnaire can be used in conjunction with physical data to help gain a well-rounded perspective of aviation maintenance issues.

5.0 PHASE 3 PLANS

Phase 3 is the final phase of the data collection currently scheduled. The challenge in Phase 3 is to complete data collection and begin to map fatigue and workplace factors to incidents and accidents. In addition, this Phase has the goal to develop models to predict when the combination of fatigue and workplace factors is likely to result in human error. Finally, Phase 3 will create a stand-alone guidelines document that can be used to help maintenance personnel understand and address fatigue and other workplace factors within their control.

5.1 Cold Weather Data Collection

As this final report is completed the research team has already scheduled additional data collection in extreme cold weather environments. During January the Mini-Loggers and Actiwatches will be on the flight line in Chicago. There are also tentative plans to collect cold weather data in Boston, in February.

Because of the general similarity in hot weather data among the three airlines, the research team anticipates similarity in cold weather data among the participants. If that is the case, the team believes that it has properly characterized the industry with respect to sleep, light, temperature, and noise. Therefore on-site data collection shall be terminated.

5.2 Anticipated Challenges

The research team has mastered the complex logistics of data collection and analysis. The process of obtaining volunteers, fitting and training them with their equipment, and motivating them to be diligent about the data collection is not straightforward. The equipment is quite expensive. The Actiwatches are approximately $1,000 USD each. Each Mini-Logger, with probes, is approximately $3,500 USD. Each of the probes is about $400. Thus, the research team cautions each participant to treat the equipment like a calibrated test set. Again, experience thus far has helped to control this challenge.

The light data was a challenge and is likely to continue as a challenge. The researchers shall consider additional ways to review the raw data prior to statistical analysis. It is possible that we may adjust the sampling time of the Mini-Loggers to better understand the duration of certain episodes of light.

The greatest challenge that faces the research task for Year 2001 is obtaining data related to maintenance error and to fatigue or environmental conditions. During 2000 another study (Johnson and Watson, 2000) reviewed installation error in heavy maintenance. That study used error data from 2 airlines and one repair station. Approximately 100 errors were reviewed for that study. The data were collected using Boeing's Maintenance Error Decision Aid (MEDA). The form has areas that address "Individual Factors", including fatigue and "Environmental Factors", including noise, hot, and cold. During that study these factors did not emerge as a cause of error. It is likely that incident investigators are not trained to discern that fatigue and/or environmental conditions were the cause of the incident or accident. The challenge will be to create awareness among maintenance error incident investigators. A secondary, and perhaps more difficult, challenge will be for maintenance personnel to attribute fatigue and/or environmental conditions to an error. Obtaining quality error data will be important to create and validate a predictive model for error caused by environmental conditions and/or fatigue. To complement airline MEDA the research team also expects to access FAA and NTSB accident and incident data that may contain references to fatigue and environmental conditions.

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8.0 APPENDIX A: TEMPERATURE AND HUMIDITY BY LOCATION AND DATE

Temperature Data - Atlanta, GA					
Date	**Max(F/ C)**	**Min(F/C)**	**Mean(F/C)**	**Dewpoint (F/C)**	**Humidity (%)**
21-Jun-00	93/33	82/28	88/31	64/18	45
22-Jun-00	90/32	73/23	81/27	69/20	66
23-Jun-00	93/34	70/21	83/28	59/14	42
24-Jun-00	91/33	72/22	83/28	63/17	51
25-Jun-00	73/23	72/22	73/22	67/19	83
26-Jun-00	91/32	68/20	75/24	66/19	74
27-Jun-00	88/31	68/20	78/25	66/18	65
28-Jun-00	73/23	70/21	72/22	68/20	88
29-Jun-00	75/24	73/23	74/23	70/21	89
30-Jun-00	79/26	64/18	71/21	60/15	69
1-Jul-00	88/31	66/19	79/26	56/13	45
2-Jul-00	88/31	66/19	77/24	64/17	65
3-Jul-00	91/33	79/26	85/29	64/17	48
4-Jul-00	90/32	73/23	80/26	67/19	65
5-Jul-00	93/34	79/26	89/31	64/17	43
6-Jul-00	93//34	79/26	86/29	69/20	58
7-Jul-00	97/36	73/23	85/29	66/18	52
Averages	87/30	72/22	80/26	65/18	61
Temperature Data - Dallas Love, TX					
Date	**Max(F/C)**	**Min(F/C)**	**Mean(F/C)**	**Dewpoint (F/C)**	**Humidity (%)**
6-Aug-00	100/38	86/30	93/34	67/19	42
7-Aug-00	100/38	86/30	94/34	67/19	41

8-Aug-00	99/37	82/28	93/33	69/20	47
9-Aug-00	9535	79/26	87/31	68/19	49
10-Aug-00	88/31	84/29	86/30	69/20	55
11-Aug-00	103/39	91/33	99/37	62/16	29
12-Aug-00	91/33	84/29	88/31	69/20	52
13-Aug-00	93/34	84/29	89/31	61/16	41
14-Aug-00	97/36	79/26	90/32	61/16	38
15-Aug-00	99/37	80/26	91/32	68/20	49
16-Aug-00	97/36	81/27	89/31	68/19	49
17-Aug-00	102/39	82/28	96/35	61/16	32
18-Aug-00	97/37	91/33	96/35	64/17	35
19-Aug-00	102/39	84/29	95/34	55/12	26
20-Aug-00	100/38	82/28	93/34	56/13	28
Averages	98/36	84/29	92/33	61/16	36.0

IAH Temperature Data - Houston, TX					
Date	**Max (F/C)**	**Min (F/C)**	**Mean (F/C)**	**Dewpoint (F/C)**	**Humidity (%)**
30-Aug-00	100/38	75/24	88/31	70/21	57
31-Aug-00	100/38	77/25	85/29	69/21	62
1-Sep-00	83/28	79/26	81/27	68/20	66
2-Sep-00	93/34	81/27	85/29	74/23	70
3-Sep-00	104/40	75/24	89/31	68/20	52
6-Sep-00	93/34	73/23	84/28	67/19	58
7-Sep-00	92/33	75/24	83/28	69/20	62
8-Sep-00	86/30	73/23	76/25	71/21	79
9-Sep-00	81/27	75/24	78/25	75/23	89
10-Sep-00	90/32	79/26	83/28	76/24	79
11-Sep-00	88/26	77/25	80/26	76/24	89
12-Sep-00	79/26	75/24	78/25	75/23	89
13-Sep-00	79/26	75/24	77/24	74/23	94

14-Sep-00	90/32	75/24	83/28	75/23	74
Averages	90/32	76/24	82/27	72/22	74.0
HOU Temperature Data - Houston, TX					
Date	**Max(F/C)**	**Min (F/C)**	**Mean (F/C)**	**Dewpoint (F/C)**	**Humidity (%)**
27-Sep-00	79/26	55/13	67/19	52/11	60
28-Sep-00	81/27	57/14	69/20	50/9	49
29-Sep-00	82/28	63/17	78/25	54/11	41
30-Sep-00	84/29	61/16	72/22	55/12	53
1-Oct-00	84/29	61/16	73/22	64/17	73
2-Oct-00	88/26	75/24	84/28	73/23	70
3-Oct-00	86/30	72/23	73/23	73/23	81
4-Oct-00	88/26	81/27	85/29	72/22	66
5-Oct-00	91/33	81/27	87/30	76/24	70
6-Oct-00	88/26	75/24	80/26	75/24	89
8-Oct-00	52/11	46/8	49/9	37/2	62
9-Oct-00	48/9	48/9	48/9	37/2	62
10-Oct-00	63/17	57/14	62/16	38/3	42
11-Oct-00	73/23	59/15	65/18	45/7	49
12-Oct-00	77/25	57/14	65/18	55/12	68
Averages	77/24	63/17	71/21	57/13	60

9.0 APPENDIX B: BLANK QUESTIONNAIRE

Directions: Please return to: Duty Manager's Office Before XXX DATE.

Measurement of Maintenance Work Environment Factors and Technician Rest Periods		
Date:		No name is necessary
1. Please check your primary role/position.		q Airframe Mod line q Avionics Interiors

	q Machine Shop Q/A Inspection q Component Apprentice (Student) q Powerplant Other__(List) q Structure/Bond
2. Gender	q Male q Female
3. Describe the amount of sleep you obtained last night.	q The usual amount q Less than usual q More than usual
4. How often do you eat breakfast?	q Daily q Almost daily q Two/three times per week q Occasionally q Seldom q Never
5. Right now how would you describe how you feel?	q Energetic Tired q Very rested Exhausted q Average
6. Not counting decaffeinated products, how many cups of coffee, tea or cola have you had in the past 24 hours?	q None 3 q 1 4 q 2 5+
7. How many drinks of alcoholic beverages have you had in the past 24 hours? Include any alcoholic drinks such as wine, beer, or hard liquor.	q None 3 q 1 4 q 2 5+

8. When do you feel the most alert?	q Beginning of shift q Just before 1st break q Immediately after mid (lunch) q Just before 2nd break q End of shift
9. Please check the age group in which you belong.	q 25 years or less q 26 – 35 years q 36 – 45 years q 46 – 55 years q 56 – 65 years q 66+
10. How many times a week do you eat at fast food establishments?	___Times per week
11. How often do you read the nutritional information labels regarding fat content of the foods that you eat?	q Always Sometimes q Very frequently q Frequently Almost never Never
12. How many miles do you commute to work each day?	q 10 miles or less q 11-20 miles q 21- 30 miles q 31 - 40 miles q 41- 50 miles q 51 – 60 miles q 61 miles and greater
13. How often do you have freedom to do your job task without supervision?	q Always Sometimes q Very frequently q Frequently

	Almost never Never
14. Please choose *three* terms that best describes your job duties.	q Very complex q Challenging q Very repetitive q Confusing q Monotonous q Ever changing q Interesting q Boring
15. How frequently do you eat food purchased from vending machines?	___Times per week
16. Do you have ready access to drinking water while on the job?	q Yes q No q Don't know
17. How often do you feel stressed at work?	q Always Sometimes q Very frequently q Frequently never Never
18. Do you enjoy your job?	q Always Sometimes q Very frequently q Frequently never Never
19. How frequently do you drink water during the day?	q None q 1-2 times per day q 3-4 times per day

	q 5-6 times per day q 6 or more times
20. How much supervision do you feel you have?	q Excessive q Very much q Somewhat more than necessary q About right q Somewhat less than necessary q Little q None
21. How often do you feel tired/fatigued at work?	q Always Sometimes q Very frequently q Frequently never Never
22. Do you use any tobacco products?	q Yes q No
23. How long have you been an aircraft mechanic/AMT?	q Less than 5 years q 5-9 years q 10-14 years q 15 – 19 years q 20 +
24. How often do you feel in control of your job/task?	q Always Sometimes q Very frequently q Frequently never Never
	q Always q Very frequently

25. How often do you work with inadequate lighting?	q Frequently never q Sometimes
26. During the past 12 months how many times have you been absent from work due to sickness?	q 0 3 q 1 4 q 2 5+
27. Do you work a second job?	q Yes q No
28. Do you feel management cares about work quality?	q Yes q No
29. How often do you work overtime?	q Always Sometimes q Very frequently q Frequently never Never
30. Check the *any of* the environmental factors that you feel affect your job performance?	q Noise Inadequate lighti q Too hot Vibration q Too cold Inadequate ventilation q High humidity Other (List)
31.How long does your one-way commute to work normally take?	q 30 minutes or less q 31 to 45 minutes q 45 to 59 minutes q 61 to 90 minutes q Greater than 90
	q 0 3

32. How many glasses of water (8 ounce glass) do you drink per day?	q 1 4 q 2 5+ Don't know
33. Check any factors you feel negatively affect your job performance.	Physical health (includes hearing and sight) q Time constraints q Peer pressure q Personal events (accident, family money problems etc) q Work place distractions/interruptions/radios q Body size/strength q Fatigue q Other (List)
34. How regularly do you eat your meals? (meals eaten at the same time each day or within 10 minutes)	q Always Sometimes q Very frequently q Frequently never Never
35. How often do you feel that you have inadequate time to complete a job assignment?	q Always q Very frequently q Frequently never q Sometimes
36. How many hours did you sleep last night?	q Less than 5 hours q 5 hrs. but less than 6 hrs q 6 hrs. but less than 7 hrs q 7 hrs. but less than 8 hrs q 8 hrs. or more

37. What shift do you presently work?	q q q	Day Afternoon (Swing) Night
38. How frequently do you exercise? (walking, jogging, swimming, bicycling etc.)	q q q q q q	Daily Almost daily Two/three times per week Occasionally Seldom Never
39. How many times per day do you use tobacco products?	q q q q q q	0 1-5 6-10 11-15 16-20 21 +
Rate your level of alertness at your work environment/operations at the start and end of shift:		
40. Alertness At the beginning of the shift.	q q q q q q q	Drowsy Not Alert Not Very Alert Somewhat Alert Alert Very Alert Extremely Alert
41. Alertness At the end of the shift.	q q q q q	Drowsy Not Alert Not Very Alert Somewhat Alert Alert

	q	Very Alert
	q	Extremely Alert

Thank you. Your input is very valuable and will help with data assessment. This information shall remain confidential. You may leave comments in this section.

10.0 APPENDIX C: QUESTIONNAIRE WITH DATA INCLUDED

Measurement of Maintenance Work Environment Factors and Technician Rest Periods

Date:		No name is necessary		
1. Please check your primary role/position.		Airframe	46.1%	Mod Line
		Avionics	7.2%	Interiors
		Machine Shop	1.4%	Q/A Insp.
		Component	1.0%	Apprentice
		Power plant	2.2%	Other
		Structure/Bond	6.0%	No resp.
2. Gender		Male	97.4%	
		Female	2.6%	
3. Describe the amount of sleep you obtained last night.		The usual amount	65.9%	
		Less than usual	29.1%	
		More than usual	3.8%	
		No resp.	1.2%	
4. How often do you eat breakfast?		Daily	32.1%	
		Almost daily	16.4%	
		Two/three times per week	11.8%	
		Occasionally	14.2%	
		Seldom	19.0%	
		Never	5.8%	
		No resp.	.6%	

5. Right now how would you describe how you feel?	Energetic Very rested Average	11.6% 9.8% 56.5%	Tired Exhausted No resp.
6. Not counting decaffeinated products, how many cups of coffee, tea or cola have you had in the past 24 hours?	None 1 2	.2% 12.2% 15.6%	3 4 5+ No resp.
7. How many drinks of alcoholic beverages have you had in the past 24 hours? Include any alcoholic drinks such as wine, beer, or hard liquor.	None 1 2	1.0% 76.6% 6.0%	3 4 5+ No resp.
8. When do you feel the most alert?	Beginning of shift Just before 1st break Immediately after mid-shift meal Just before 2nd break End of shift Missing	53.7% 23.0% 5.6% 5.4% 10.6% 1.6%	
9. Please check the age group in which you belong.	25 years or less 26 – 35 years 36 – 45 years 46 – 55 years 56 – 65 years 66+ years No response	2.6% 29.7% 41.7% 18.2% 7.0% .4% .4%	
10. How many times a week do you eat at fast food establishments?	2.84 Times per week on average		
11. How often do you read the nutritional information labels regarding fat content of the foods that you eat?	Always Very frequently	12.4% 10.0%	Seldom Almost never

	Frequently	16.6%	
	Sometimes	22.8%	Never
12. How many miles do you commute to work each day?	10 miles or less		20.2%
	11-20 miles		24.4%
	21- 30 miles		21.6%
	31 - 40 miles		17.8%
	41- 50 miles		6.6%
	51 – 60 miles		2.8%
	61 miles and greater		6.4%
13. How often do you have freedom to do your job task without supervision?	Always	31.9%	Seldom
	Very frequently	31.7%	Almost never
	Frequently	23.0%	Never
	Sometimes	8.0%	No resp.
14. Please choose *three* terms that best describes your job duties.	Very complex		21.8%
	Challenging		73.3%
	Very repetitive		38.1%
	Confusing		6.0%
	Monotonous		12.8%
	Ever changing		38.3%
	Interesting		59.1%
	Boring		11.0%
	Percent of Participants		**Selecting Each Item**
15. How frequently do you eat food purchased from vending machines?	1.89 Times per week on average		
16. Do you have ready access to drinking water while on the job?	Yes		97.4%
	No		.4%
	Don't know		.2%
	No response		

			2.0%
17. How often do you feel stressed at work?	Always	3.8%	Seldom
	Very frequently	5.0%	Almost never
	Frequently	11.4%	Never
	Sometimes	46.7%	No resp.
18. Do you enjoy your job?	Always	30.9%	Seldom
	Very frequently	20.8%	Almost never
	Frequently	25.5%	Never
	Sometimes	19.2%	
19. How frequently do you drink water during the day?	None	2.2%	
	1-2 times per day	15.8%	
	3-4 times per day	31.7%	
	5-6 times per day	20.2%	
	6 or more times	31.1%	
20. How much supervision do you feel you have?	Excessive		3.2%
	Very much		6.4%
	Somewhat more than necessary		11.4%
	About right		65.7%
	Somewhat less than necessary		4.0%
	Little		6.4%
	None		2.2%
	No response		.6%
21. How often do you feel tired/fatigued at work?	Always	3.8%	Seldom
	Very frequently	4.2%	Almost never
	Frequently	16.8%	Never
	Sometimes	51.9%	No resp.
22. Do you use any tobacco products?	Yes 29.1%		

	No 70.7%		
23. How long have you been an aircraft mechanic/AMT?	Less than 5 years 5-9 years 10-14 years 15 – 19 years 20 + years No response		10.6% 14.8% 37.7% 17.8% 18.6% .4%
24. How often do you feel in control of your job/task?	Always Very frequently Frequently Sometimes	32.7% 29.3% 25.3% 9.2%	Seldom Almost never Never No resp.
25. How often do you work with inadequate lighting?	Always Very frequently Frequently Sometimes	8.2% 15.2% 22.2% 35.6%	Seldom Almost never Never No resp.
26. During the past 12 months how many times have you been absent from work due to sickness?	0 1 2	32.5% 21.6% 21.0%	3 4 5+ No resp.
27. Do you work a second job?	Yes 7.0% No 93.0%		
28. Do you feel management cares about work quality?	Yes 77.8% No 21.6% No response .6%		
	Always	7.6%	Seldom

29. How often do you work overtime?	Very frequently Frequently Sometimes	8.0% 19.0% 33.5%	Almost never Never No resp.
30. Check the *any of* the environmental factors that you feel affect your job performance?	Noise Too hot Too cold High Humidity Inadequate lighting Vibration Inadequate ventilation Other **Percent of Participants**		58.3% 69.3% 25.1% 64.3% 42.5% 6.4% 13.6% 8.8% **Selecting Each Item**
31.How long does your one-way commute to work normally take?	30 minutes or less 31 to 45 minutes 45 to 59 minutes 61 to 90 minutes Greater than 90 No response	55.7% 29.3% 9.2% 3.8% .2% 1.8%	
32. How many glasses of water (8 ounce glass) do you drink per day?	0 1 2 3	3.2% 6.6% 13.6% 17.4%	4 5+ Don't know No response
33. Check any factors you feel negatively affect your job performance.	Physical health (includes hearing & sight) Time constraints Peer pressure Personal events (accident, family or money problems, etc.) Work place distractions/ interruptions/ radios		

	Body size/strength Fatigue Other *Percent of Participants Selecting Each Item*		
34. How regularly do you eat your meals? (meals eaten at the same time each day or within 10 minutes)	Always Very frequently Frequently Sometimes	15.8% 18.0% 31.7% 20.2%	Seldom Almost never Never No resp.
35. How often do you feel that you have inadequate time to complete a job assignment?	Always Very frequently Frequently Sometimes	3.8% 6.8% 15.6% 39.5%	Seldom Almost never Never No resp.
36. How many hours did you sleep last night?	Less than 5 hours 5 hrs. but less than 6 hrs 6 hrs. but less than 7 hrs 7 hrs. but less than 8 hrs 8 hrs. or more No response		15.2% 23.4% 32.5% 20.6% 7.8% .4%
37. What shift do you presently work?	Day Afternoon (Swing) Night No response		43.3% 24.6% 30.3% 1.8%
38. How frequently do you exercise? (walking, jogging, swimming, bicycling etc.)	Daily Almost daily Two/three times per week Occasionally		10.4% 9.4% 23.6% 28.5%

	Seldom	19.8%
	Never	7.2%
	No response	1.0%
39. How many times per day do you use tobacco products?	0	68.3%
	1-5	8.4%
	6-10	7.0%
	11-15	5.6%
	16-20	4.8%
	21 +	4.2%
	No response	1.6%
Rate your level of alertness at your work environment/operations at the start and end of shift:		
40. Alertness At the beginning of the shift.	Drowsy	3.2%
	Not Alert	.8%
	Not Very Alert	3.2%
	Somewhat Alert	14.8%
	Alert	45.1%
	Very Alert	24.8%
	Extremely Alert	6.4%
	No response	1.6%
41. Alertness At the end of the shift.	Drowsy	3.6%
	Not Alert	2.2%
	Not Very Alert	6.0%
	Somewhat Alert	19.8%
	Alert	44.3%
	Very Alert	18.0%
	Extremely Alert	4.2%
	No response	1.8%

Thank you. Your input is very valuable and will help with data assessment. All individual information will be considered confidential. You may leave comments in this section.