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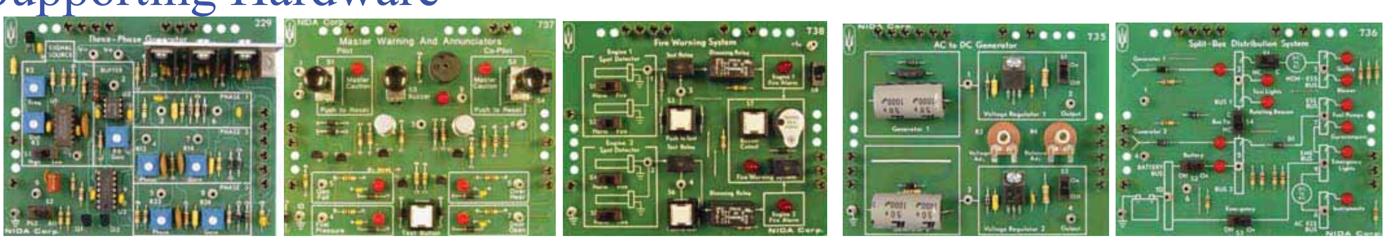

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A Survey of Technician Fatigue in Aircraft Maintenance Operations

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ABSTRACT

A less then optimal amount of data exists on fatigue experienced by federally certificated Aircraft Maintenance Technicians (AMTs). This paper presents the analysis of a survey conducted to evaluate the prevalence and severity of fatigue experienced by certificated Airframe, Powerplant and Repair technicians in a variety of aircraft maintenance, repair and inspection settings. The recognition of fatigue and its effects on technicians performing critical inspection procedures and maintenance on aircraft is central to a safe and efficient National Airway System. Despite a heightened awareness for the value of Human Factors training in aircraft maintenance operations, fatigue continues to be a major concern for the overall health and safety of AMTs. In both corporate and scheduled operations, the need for proper rest and sleep and the demand for dependable aircraft availability often conflict. Maintenance errors related to fatigue are particularly insidious since incorrectly installed parts, improper repairs or incomplete maintenance procedures are often concealed behind robust structures, secured panels or closed cowlings. While Title 14 Code of Federal Regulations (Title 14 CFR) mandating rest rules for Air Traffic Controllers, Flight Crews and Cabin Attendants have existed for decades, there are few legal mandates dictating mandatory rest periods for AMTs. The paper will also attempt to identify the significance of individual and managerial efforts to reduce fatigue and related errors experienced by Aviation Maintenance Technicians.

INTRODUCTION

Since humans first began to fly controllable powered aircraft, fatigue has consistently been an issue of concern for regulators and accident investigators alike. Whether fatigue is experienced on the ground or in the air, the insistent pace of operating and maintaining aircraft in the modern world consistently approaches the limits of human endurance. In the memoir of his trans-Atlantic solo flight in 1927, Charles A. Lindbergh described in detail how the aircraft was intentionally designed with unstable flight characteristics to help Lindbergy resist the onslaught of fatigue and keep him awake. The cockpit was purposely designed to be small, cramped and with limited visibility. Making the cockpit seat from hard wicker and mounting it at an awkward angle forced Lindbergh to constantly adjust his posture during the flight. Despite these intentional design innovations, Lindbergh wrote how, just 4 hours into his historical endeavor, fatigue began to affect his performance:

> *"If I could throw myself down on a bed, I'd fall asleep in just an instant. In fact, if I didn't know the results, I'd fall asleep just as I am, sitting up in the cockpit-I'm beyond the stage where I need a bed, or even to lie down. My eyes feel dry and hard as stones. The lids pull down with pounds of weight against their muscles (The Spirit of St. Louis, 1953, p.233)."*

Lindbergh's successful landing in Paris made aviation history and spurred explosive growth in an industry in dire need of a catalyst. Perhaps as significant as his trans-Atlantic flight, Lindbergh's efforts to combat the anesthetizing onset of fatigue may be the first practical realization of human endurance in the aviation industry.

For this study, fatigue is defined as an extended state of exhaustion combined with a noticeable decreased capacity for physical and cognitive performance (Hawkins, 1987). Numerous studies indicate that fatigue is equally experienced by aircrews, ground based controllers, however, little scientific data exists detailing technician fatigue encounters (Petrie & Dawson). Despite the varying responsibilities of this diverse group, they all have a common moral and regulatory obligation to ensure safety of flight and airworthiness.

Human physiology has always been a major component of any aircraft accident investigation. Contemporary accident reports often include discussions of Crew Resource Management techniques, equipment failure, disorientation, stress and fatigue. Fatigue can be caused by many factors, including emotional, physical and mental conditions. Even moderate levels of fatigue can produce performance decreases comparable to levels of drug or alcohol intoxication that would generally be unacceptable whether driving, operating safety sensitive equipment or performing aircraft maintenance and repairs (Reinhart, 1996).

Every year since 1990, the National Transportation Safety Board (NTSB) has issued an inventory of its "Most Wanted Safety Improvements." The NTSB selects these topics to focus attention on problems it believes have the greatest impact on transportation safety. The NTSB also uses the list to offer proposals for Federal Aviation Administration (FAA) action concerning known hazards, and follows the progress of the FAA's efforts to mitigate the identified risks. In 1999, the NTSB publicly recognized for the first time the seriousness of fatigue experienced by aircraft technicians when it included fatigue issues on the most wanted list. In its recommendations, the NTSB suggested the FAA:

> *"Establish scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider human sleep and rest requirements (NTSB, 2006)."*

While the NTSB acknowledged research on technician fatigue issues has been conducted, it also notes in the request for action that for several years, no significant progress has been reported.

In aviation maintenance, aircraft inspection and repair procedures are often performed in difficult and challenging situations. Conditions can be conducive to temperature related stresses, including exposure to freezing and cold temperatures for extended periods of time, or even rain or snow outside when unscheduled or emergency repairs are performed. While the majority of procedures are completed inside hangars and related repair shops, these environments often lack adequate lighting, heat, and air conditioning necessary for precise operations. Noise is also a major irritation of the trade, caused by power tools or the testing of various aircraft systems in addition to normal airfield operations. Inspecting and repairing aircraft is a physically demanding occupation, which often requires climbing on ladders or scaffolds, awkward postures under wings or pylons, and fitting into confined spaces. Cuts, bruises, burns and falls are significant occupational hazards. In addition, exposure to a variety of hazardous chemicals, elevated radiation levels and lifting heavy components and materials is a normal job expectation (U.S. Department of Labor, 2008

In many ways similar to flight operations, technicians often function under time pressures and economic concerns to maintain operational schedules and reduce costs. At the same time, technicians can never sacrifice airworthiness or safety of flight concerns to speed up a procedure. They must remain conscious of the legal responsibilities and moral consequences of their work performance. Since most commercial flights and the majority of other non-scheduled aircraft operations occur during normal business hours, many aircraft inspection, maintenance and repair operations are conducted during evening and late night shifts. Late flights, unscheduled maintenance, and comprehensive procedures often lead to extended shifts, missed breaks and meals. These pressures to return the aircraft to service expeditiously can accelerate the onset of fatigue.

Performing critical maintenance and inspection tasks that necessitate intense concentration and vigilance are the most hazard-laden when accomplished while fatigued impaired. For example, many modern turbo-fan engines require periodic maintenance procedures to assess the operational condition of internal gas turbine components using borescope equipment. After accomplishing the required cleaning and inspection, if a minute crack or other defect is overlooked, a catastrophic engine failure could occur.

In an attempt to identify fatigue levels experienced by AMTs, this paper presents a literature review of fatigue commonly experienced in a variety of aviation settings. A review of several fatigue related incidents obtained through the Aviation Safety Reporting System (ASRS) along with an NTSB accident report is included. Most significantly, the responses and interruptions of a web-based survey of experiences in the aircraft maintenance sector are also provided. The paper concludes with several suggestions regarding AMT fatigue countermeasures and a recommendation for continuing investigation of AMT related fatigue issues.

LITERATURE REVIEW

Ongoing analysis of human performance problems clearly show that fatigue related errors remain a major contributor to civilian and military aircraft accidents. Rest periods for controllers, flight attendants and pilots have long existed and continue to be modified to reflect changing work patterns, advanced technologies and employment agreements. However, despite the best intentions of researchers, employers and regulators, attempting to regulate the human body and ordering it to rest when opportune remains elusive.

Notwithstanding the many noteworthy accomplishments of nearly a century of flight, human factors in aircraft maintenance operations were not studied comprehensively until the late 1980s (Patankar and Taylor, 2004). Since then, a small number of studies have produced limited data associated with fatigue as experienced by technicians. Despite limited research specific to fatigue encountered by AMTs, these studies indicate that fatigue not only degrades human performance but are often cited as a primary cause of errors (Struach, 2002). Reinhart (1996) found that fatigue is the universal symptom associated with sleep deficiency and erratic circadian rhythms along with many additional stresses not at all exclusive of the aerospace industry.

While the literature review identified extensive conclusions concerning fatigue in various flight and controller scenarios, the researcher discovered limited findings directly related to exhaustion suffered by AMTs. Despite a narrow research foundation, the researcher is convinced that an expansive source of key findings concerning fatigue in comparable safety sensitive occupational settings can be easily adapted to aircraft maintenance and inspection operations.

To comprehend the current state of rest requirements for technicians, it is important to review federal regulations mandating rest periods for technicians. Title 14 CFR Parts 25, 43, 65, 121, 135 and 145 require that technicians either working privately under a contract, or employed by maintenance organizations, have adequate facilities, training and equipment necessary to perform all the work and required inspections appropriate to their rating. The present regulations affecting AMTs hours-of-service in Title 14 CFR Part 121 states:

> *"Each certificate holder shall be relieved from duty for a period of at least 24 consecutive hours during any seven consecutive days, or the equivalent thereof within any one calendar month (Title 14 CFR Part 121.377)."*

This rule applies to persons who work on aircraft or components installed on aircraft operated under the provisions of Title 14 CFR Part 121, normally considered scheduled air carrier operations. This means a technician may work 24 consecutive days in a calendar month with no daily hour duty time limitations, take 4 days off and be in compliance with the provisions of this rule. If a technician is employed by a Title 14 CFR Part 145 Repair Station that maintains or repairs components installed on aircraft operated by a Part 121 certificate holder, then in most situations, the duty limits outlined it Title 14 CFR Part 121.377 apply.

While regulators may dictate rest standards as part of an organization's manufacturing approval or repair station certificate, it is important to note that these requirements are location specific and consequently, not applicable to equivalent or different operations. Presently, there are no federally mandated rest regulations for technicians performing maintenance and inspections procedures under Title 14 CFR Part 25, 43, 65, 135 and 145 (FAR/AMT, 2007).

FATIGUE AND MAINTENANCE SCHEDULING

Aviation is certainly not the only industry susceptible to fatigue related accidents and mistakes. Maritime operations, industrial settings and health services are also vulnerable. However, in aircraft maintenance, fatigue related mistakes can take months to discover, be expensive to repair and may cause accidents and possible death. Everyone experiences fatigue occasionally, either physically or cognitive, from a long drive, illness, or just the consequences of living in a fast paced, competitive society. The key to decreasing the effects of fatigue experienced by technicians is developing an effective program to minimize human error (Gamauf, 2006).

To understand how to recognize the symptoms and resist the onset of fatigue, it is important obtain a basic understanding how fatigue affects the individual. The human body operates on a predictable pattern or cyclic rhythm. This cycle, know as circadian rhythm (from Latin: circa diem, when translated means about a day), describes how the human body cycles through periods of wakefulness and restfulness over a period of about a day, or normally 24 hours. Similar to the Earth's 24 hour rotation through night and day, the body's internal clock is influenced by the cycles of daylight and darkness. Regulated by the hypothalamus region of the brain, this biological cycle is significantly influenced by environmental signals and coordinates the body's natural rhythms that make most people active during the day and restful at night (Caldwell and Caldwell, 2003).

Generally, all humans experience similar episodes of circadian behavior, but there are individual differences how each individual copes with fatigue. This varies with age, gender and overall individual health. Fatigue is often described as physical and/or mental exhaustion that can be triggered by stress, medication, overwork, mental and physical illness or disease (Centers for Disease Control and Prevention, 2007). Being tired is the body's natural way of indicating the need for rest and sleep. Since numerous studies across various modes of transportation show fatigue to be an underlying factor in a significant percentage of accidents, this study will be concerned with identifying the nature and extent of fatigue in the aircraft maintenance operations (Reinhart, 1996).

Reinhart (1996) presented sleep debt as a cumulative effect that continues to escalate when individuals consistently fail to obtain the recommended 7-8 hours of sleep each night. Sleep deficit experienced by technicians' results in an accumulation of sleep debt as categorically serious as symptoms suffered flight crews, cabin attendants and controllers. Examination of supporting material for this study found that the major contributing factors and symptoms for fatigue most commonly experienced by technicians consist of:

Lack of sleep has presented in numerous investigations as a major contributor to deteriorated performance. In the aircraft maintenance workplace, alertness while performing critical job functions is essential for the safety of the flying public. In situations where technicians may be working through the night either alone or with reduced supervision, when cognitive skills are crucial, the importance of being fully awake is obvious. The inability to obtain adequate rest has been shown to cause increased reaction time when performing even routine tasks along with an inability to concentrate when conducting repetitive tasks. This cognitive degradation often results in short term memory loses, along with increased distraction which may impair judgment and decision making (Reinhart, 1996).

Irregular circadian rhythms are disruptions in a person's "internal body clock" which regulates the biological cycles including sleep and wake patterns, performance levels, moods, digestion, and other bodily functions are all genetically programmed to take place at certain times. Operating on a 24-hour cycle, the brain relies on external influences such as daylight and established patterns to set our internal body clocks. Scientists have identified hundreds of biological variables in humans that are circadian in nature. This includes physical things like body temperature, hormone production, sleep-wake cycles, and psychological things like memory, and ability to perform mental tasks. Disturbing these established functions is similar to those who travel frequently across several time zones and experience "jet lag." Shift workers that work days one period and nights in another can experience dynamic changes in alertness and performance. Because circadian rhythms do not adjust as rapidly as duty schedules may change, a technician may be fatigued for extended periods, resulting in cumulative sleep debt and progressive performance decrements including declining health status (Reinhart, 1996).

Duty schedules requiring shift work does create productivity advantages; aircraft are available at times when the majority of the public expects to fly. Some of the most serious problems technicians encountered are frequent sleep disturbance and associated excessive sleepiness. However, sleepiness caused by rotating work shifts while engaged in aircraft maintenance tasks can lead to poor concentration, accidents, errors, injuries and possible fatalities (National Sleep Foundation, 2007).

Achieving sufficient sleep can be a problem for workers whose shift ends in the morning. They have been awake all night, when their body wanted to sleep and now have to sleep when they should be awake. They also have to try to sleep when the majority of the community is awake and often noisy (Reason & Hobbs, 2003).

Aviation Safety Reporting System (ASRS) incident reports were examined to determine if fatigue has been reported as the cause of aircraft accidents, compromised safety, or ineffective operations. Information gained from the ASRS data base revealed a multitude of incidents specific to fatigued technicians. In an effort to present contemporary information, this study limited its review to incidents posted between 2001 and present. The ASRS search was accomplished using the following terms: tired, fatigued, exhausted, stress and lack of sleep. Incorporating ASRS reports recognizes several significant precincts.

First, as a consequence of voluntarily participation in the ASRS, reports concerning fatigued technicians do not accurately establish the actual number of occurrences, specific type and location of operations, aircraft type(s), procedures, environmental conditions, staffing, training and oversight. Second, ASRS is subject to a number of reporting biases. Despite limited immunity from regulatory enforcement action provided by ASRS program, many AMTs remain unaware of its existence or are otherwise suspicious of possible federal enforcement action that may result in certificate suspension or renovation.

In addition, it is possible that AMTs experience confusion reporting unsafe conditions under the guidelines of the Federal Aviation Administrations (FAA) separate Service Difficulty Reporting System (SDRS) and the ASRS. The SDRS is a database of maintenance incidents collected by the FAA for the purpose of tracking repair problems with commercial and private aircraft including their components. Finally, the author is unaware of any assessment revealing how often fatigue issues go unreported by AMTs. Consequently, the significance of ASRS reports lies on the researcher explaining the consequence of the specific AMT fatigue related incident.

The following ASRS report narratives are presented as examples of AMT fatigue and the effects on safe and efficient aircraft maintenance operations. Referred to by their ASRS Access Control Numbers (ACN), these reports imply that fatigued technicians have difficulty completing critical procedures and required inspections items, suffer a lack of confidence completing unfamiliar tasks, sensitivity to changing work priorities and endure the same general symptoms of fatigue as other safety related occupations. Since ASRS reports are heavily edited with NASA abbreviations, these reports have been condensed and edited for clarity to emphasize the relevant fatigue issues:

> ACN 725413- At approximately 5 AM in the morning, the AMT installed a Boeing 737-700 series brake assembly on an 800 series aircraft. The mistake was discovered several days later when an inventory audit revealed the missing 700 series brake assembly. The AMT stated that fatigue affected his ability to concentrate and he did not note the different part numbers of the brake assemblies that looked identical and were located next to each other in the parts room. The aircraft was located on the operator's route, removed from service and an emergency work order issued to install the correct brake assemblies.
>
> ACH 711948- Reporting only 5 hours of rest in the previous 40, the AMT was interrupted several times performing an overnight check on an A-320 by an arriving general aviation aircraft with a dead battery. Concerned with the impending closure of the airport for runway maintenance that would strand the general aviation pilot, the AMT did not notice he had left the A-320 main battery switch in the on position over night. The next morning, the drained battery was insufficient to start the A-320 engines, and along with other ground support equipment failures, the scheduled departure was delayed.
>
> ACN 653118- Because of a long commute, the AMT was awake more than 24 hours and reported to work very tired. Several hours into his shift, the technician installed a cabin escape slide on a Boeing 737-800 and released the aircraft for service without the required oversight approval or removing the safety pin. The AMT did not call for the required inspection because he performed other work on the aircraft that did not required a secondary inspection and his fatigued state caused him to overlook the necessity to call for a release authorization for the escape slide.

ACH 628207- Working with only 3 days rest in the previous 30, the fatigued technician rationalized it would acceptable to use a torque wrench that was out of calibration by only a few weeks to re-torque the wings bolts on an aircraft that had experience in-flight turbulence. A follow up inspection of the procedure revealed that the wings bolts and associated hardware were installed incorrectly prior to the rough air encounter and not noticed during the re-torque procedure.

ACH 625274- Technician reported to work very tired and stressed because his son was readmitted to the hospital following a second surgery for cancer. During his shift, the technician failed to calibrate the emergency escape slide inflate bottle test stand to the required 1% accuracy. The test rig was subsequently used on several MD-80 and B-757 series aircraft. While reviewing work cards, maintenance control discovered the mistake and recalled all the emergency slide inflation cylinders affected for replacement and hydrostatic testing.

From the NTSB database, technician fatigue was identified as a contributing factor in one of the worst aircraft accidents in recent years (NTSB, 1997). On May 11th, 1996, ValuJet Flight 592 crashed into the Florida Everglades shortly after takeoff from Miami International airport. The accident killed all 111passengers and crew onboard. The NTSB determined the cause of the crash was improperly stored oxygen generators that ignited an intense fire in the cargo bay resulting in loss of control of the aircraft. As part of the investigation process, NTSB investigators also examined operational and staffing procedures at SabreTech, the maintenance facility contracted by ValuJet to inspect and repair several of the airlines aircraft.

When SabreTech technicians removed additional oxygen canisters from other ValuJet aircraft in March of 1996, the company was experiencing manpower and parts delays that complicated its ability to complete the contract and faced large financial penalties to ValuJet. To expedite the inspection and maintenance of the remaining ValuJet aircraft at its facility, SabreTech canceled vacations for all its technicians and contract workers and required them to work 12 hour duty days, seven days a week until the remaining procedures were completed and the aircraft returned to service at ValuJet (Strauch, 2002).

While the critical error in the ValuJet accident was loading improperly secured and unexpended oxygen generators in the airplane's cargo compartment, the NTSB issued a total of 27 recommendations to address serious deficiencies identified during the investigation. Several recommendations dealt with antecedents related to FAA oversight, proper maintenance documentation and the handling of hazardous material. Concerned with fatigue and weariness experienced by the SabreTech workforce, NTSB Recommendation A-97-71 asked the FAA to: "Review the issue of personnel fatigue in aviation maintenance, and then establish duty time limitations…(NTSB, p.139). "

Based on the above, the need to further assess the current state of AMT fatigue is clear. Since Lindbergh's epic flight, significant industrial and regulatory changes have occurred. However, while programs designed to understand all the factors that cause and contribute to fatigue continue to evolve, ASRS reports and NTSB suggestions highlight crucial areas of maintenance human factors and the need for further research.

METHODOLOGY

A web-based survey of 23 questions was developed utilizing SurveyMonkey™, an on-line survey website. The survey included 4 sections establishing credentials and non-personally identifiable items such as gender, age, federal certificates held, experience levels and the applicable Title 14 CFR under which a technician is exercising his or her certificate privileges. The survey also included questions related to rest and sleep periods, duty time, shift duration, overtime and fatigue experienced while working on aircraft. Using logic developed by SurveyMonkey, the survey attempted to evaluate if fatigue is an observable event in aircraft maintenance operations. Several questions concerning managerial efforts to educate and manage technician fatigue were also incorporated into the survey. A copy of the survey is included in this study as Appendix A.

The major goal of the survey was to document the severity and frequency of fatigue experienced by technicians in relation to number of consecutive work days, length of work shifts and rest periods. Survey validity was verified by conducting a field test in March, 2007 during the Tennessee Mid-South Aviation Maintenance Conference conducted annually in Nashville. The survey was administered to 46 participants who voluntarily completed the survey and provided feedback on survey structure, syntax and question placement. Several changes were made to the survey based on the recommendations of the test group prior to its full distribution. The final survey was comprised of 23 questions created from the test project and from a National Aeronautics and Space Administration (NASA) survey that consisted of 107 questions related to pilot fatigue.

Per SurveyMonkey procedure, a link was included on each survey page to allow individuals the opportunity to decline participation in the survey. SurveyMonkey logic does not record internet protocol addresses in responses submitted, ensuring confidentiality for the participant while discouraging future follow-up by the researcher.

Because the purpose of this survey was to define fatigue issues experienced by technicians across a spectrum of aircraft maintenance sectors, electronic newsletters from the Aircraft Maintenance Technology Society and the Professional Aviation Maintenance Association were utilized as distribution methods to reach potential participants. Both organizations are dedicated to the advancement of the aircraft maintenance profession and produce electronic, newsletters reporting contemporary aviation news related to industry trends, federal regulations, safety and airworthiness. Combined, these two newsletters are distributed to approximately 1,500 individuals including technicians, repairmen, federal inspectors and safety representatives. Knowing that not all of the subscribers were certificated technicians or repairmen, the response rates were expected to be low because everyone that received information about the survey was not eligible within study parameters to participate. The survey was conducted from July, 2007 to September, 2007.

At survey-end, a total of 457 responses were received, resulting in a 20.77% response rate. As response rates for self-administered surveys (either via mail or online) are normally well below this number, it was decided by the researcher that this response rate was sufficient for the purposes of this study. More importantly, this response favors comparably and is in fact slightly above the response rate for a NASA survey of pilot fatigue accomplished in 2000.

This survey relied heavily on the 2000 NASA study Crew Factors in Flight Operations XIII: A Survey of Fatigue Factors in Corporate/Executive Aviation Operations, for question content and placement. The NASA study intentionally used percentages as the principal method of interpreting descriptive statistics. Consequently, this study used percentages as its predominant method of analysis to determine how duty times, shift schedules and inadequate rest contributed to technician perception of fatigue levels.

LIMITATIONS

The researcher acknowledges that the aircraft maintenance industry is unique in that it utilizes a significant number of non-certificated personnel in the workforce, both in the United States and foreign counties. These unlicensed aircraft personnel routinely perform comprehensive aircraft maintenance and repairs procedures. This unique arrangement is allowed by federal statutes that require the continual guidance and supervision of non-certificated mechanics and provisional employees by properly trained and certificated technicians.

Notwithstanding the presence of non-certificated technicians in the workforce, federal standards for aircraft maintenance and inspection procedures clearly establish responsibility for determining airworthiness and approval for return to service to certificated Airframe and/or Powerplant rated technicians, holders of an current Inspection Authorization, or properly documented Repairman rating. Consequently, responses to the survey were restricted to holders of an Airframe and/or Powerplant certificate, Inspection Authorization or Repairman endorsement.

DATA ANALYSIS

Questions 1 and 2 of the survey shown in Table 1, indicates that the aircraft maintenance industry is comprised of a mature workforce dominated by males. Table 1also illustrates 97.7% of respondents were at least 25 years old while a slight majority (50.8%) of respondents reporting to be in the 45-64 age group.

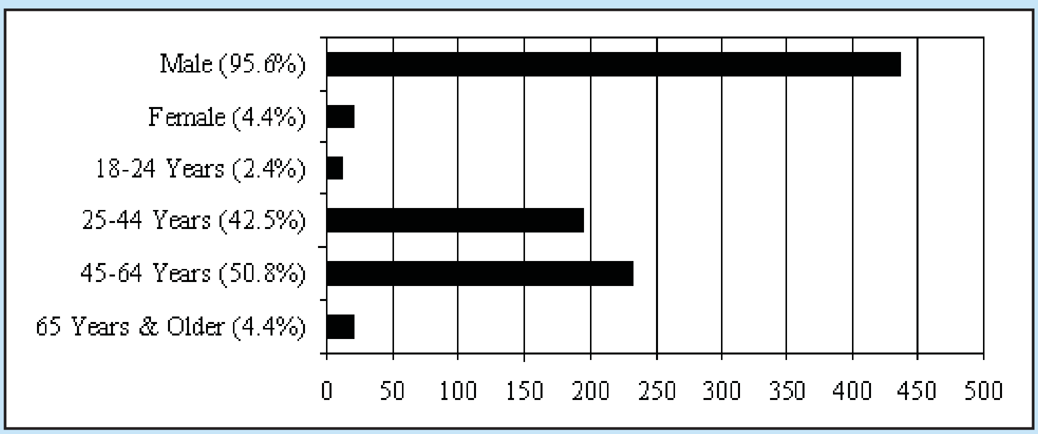

Table 1. Demographics

EXPERIENCE

Survey results shown in Table 2, indicate a skilled and knowledgeable labor force where 78% or participants have 11 or more years as certificated technicians or repairman.

	5 Years or Less	6-10 Years	11-15 Years	16-20 Years	More than 20 Years
Technical Experience	8.1%	13.1%	12.0%	16.4%	50.3%

Table 2. Survey Question 3: Experience

CREDENTIALS

Table 3 shows that an overwhelming number of participants possess both an Airframe and Powerplant certificate, while slightly less than 12% hold an Inspection Authorization. Nearly half of respondents, 43.5%, reported holding a valid Repairman certificate.

Airframe	Powerplant	Inspection Authorization	Repairman
92.3%	11.9%	43.5%	50.3%

Table 3. Survey Question 4: "What certificates/ratings do you currently hold?"

EMPLOYMENT

Table 4 shows responses to survey question 5 indicating that AMTs are almost evenly distributed in the industry with 40% employed by Part 121 operations and 42% active in Part 145 repair stations. Title 14 CFR Part 135 on-demand charter operations employ nearly 30% of respondents, while the remaining, 37%, are active in either the manufacturing sector or perform their activities privately or possibly under contract.

Part 25	Part 43/65	Part 121	Part 135	Part 145
8.1%	28.9%	40.3%	28.7%	42.2%

Table 4. Survey Question 5: Employment Sector

NORMAL DAY

Figures 1 through 4 describe participants' responses to questions six through nine concerning sleep quality, duration and the lingering effects of fatigue and alertness when awake and working. The sleep data complied indicates that a majority of AMTs experience unsatisfactory sleep patterns at noteworthy levels. Significant responses seen in Figure 1 include 55.2% reporting irregular circadian rhythms, achieving only 5-6 hours of uninterrupted sleep. Survey response showed that almost 25% of participants average 4 hours or less sleep each day. As seen in Figure 4, a combined 59% answered "Often" or "Occasionally" when asked if they felt fatigued or lacking in sleep.

As seen in Figure 4, data analysis showed 42% of AMTs experience trouble falling to sleep regularly, while 35.7% reported work related anxiety interfering with restful sleep (Figure 3). While these responses do not represent a majority of participants, in the context that more than 25% of the total work force endures unsatisfactory sleeps periods, further investigation is certainly warranted. The relatively large percentage shown in Figure 2 reporting lacking restful sleep and resulting fatigue may imply that AMTs are not fully aware of their unique sleep patterns and that fatigue may result.

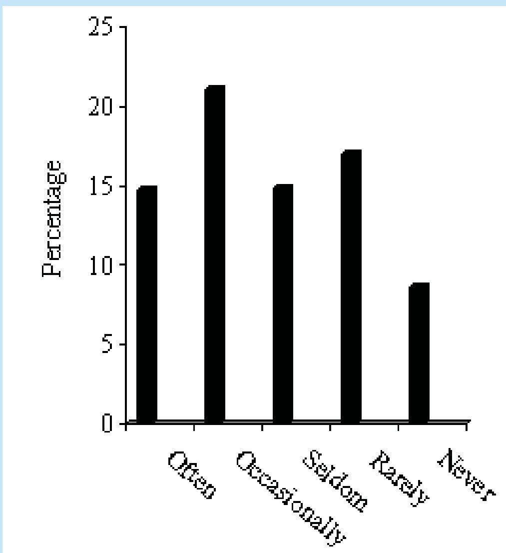

Figure 1. Hours of Uninterrupted Sleep

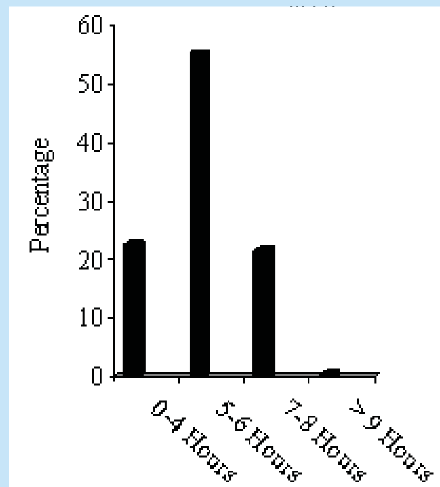

Figure 2. Anxiety Interference

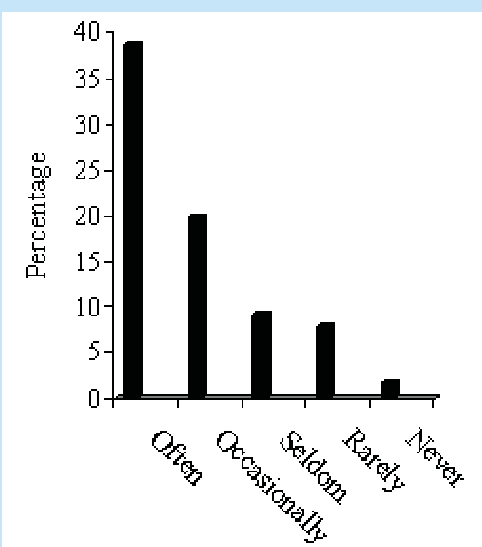

Figure 3. Fatigued

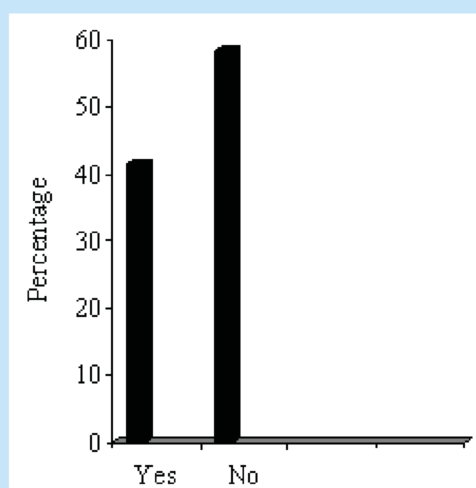

Figure 4. Trouble Falling Asleep

AMTs employed at most inspection and repair facilities report on one of three shifts: day, afternoon and night (commonly referred to as third shift). Tables 5 through 7 relate responses to survey questions 10 through 12 concerning number of days worked and duty time involving maintenance procedures on aircraft. While survey results represent all 3 shift periods, 63% report working the day shift beginning as early as 5AM.

5 AM to 12 Noon	63.2%
12 Noon to 5 PM	10.6%
5 PM to Midnight	12.6%

Table 5. Normal Shift

3 or less days	0.7%
4 – 5 days	62.8%
6 – 7 days	28.7%
8 – 9 days	2.1%
10 – or more days	5.7%

Table 6. Days worked in a row

0 – 1 times	14.3%
2 – 4 times	17.7%
5 – 7 times	17.2%
8 – 10 times	10.3%
11 – or more times	40.5%

Table 7. Extended duty days in the past month

As seen in Table 5, 63% of AMTs have a work schedule of four to five consecutive days. Interesting, more than a quarter, 31%, reported working between six and nine days without a day off (Table 6). Extended duty hours appear to be the norm for most AMTs, with 40% indicating they worked an extended shift (more than 8 hours) 11 or more times in the past month (Table 7).

Table 8 contains data collected from questions 13 and 16 showing that a majority of participants (61%) do not have the benefit of a fatigue or rest period policy.

Data indicating how early AMTs report to work is presented from question 15 in Table 9. As shown, 52% of respondents are expected to report to work at least 30 minutes early to participate in training updates, security activities or other employer related activities. These activities can affect the length and complexity of daily routines.

In fact, these non-aircraft related activities have the potential of preventing AMTs reporting for assignments neither properly rested nor feeling alert. In these conditions, it is possible that technicians may be susceptible to the initial onset of fatigue even before beginning their assigned tasks.

	Yes	No
Does your employer have a written policy or guidelines concerning rest periods for technicians?	39%	61%
Are you required to arrive at work to arrive at work before your shift begins for job assignments?	50.1%	49.9%

Table 8 . Rest Guidelines

15 minutes or more	46.5%
30 minutes or more	40.8%
1 hour or more	12.7%

Table 9. Preshift reporting

To ensure the highest level of safety and reliability, employers, technicians and federal regulators share explicit responsibilities to manage and prevent fatigue. At a minimum, these responsibilities include ensuring that AMTs obtain adequate rest so that fatigue does not adversely affect their performance. Work place pressure to achieve financial expectations and meet demanding flight schedules while increasing efficiencies can be problematic for flight crews as well as AMTs. Data presented in Figure 5 represents question 14 and indicates that 70.3% of respondents have been asked or felt pressured to work on aircraft while fatigued. Recognizing the large response rate, it is obvious that despite the considerable foundation of scientific knowledge concerning fatigue related impairment suffered by their flying counterparts and ground based controllers, employers and AMTs consider fatigue a norm of the inspection and maintenance process. Not surprisingly, Figure 6 relates results from survey question 17 that an overwhelming majority of respondents (83%), believed fatigue in aircraft repair, inspection and maintenance operations is a common occurrence.

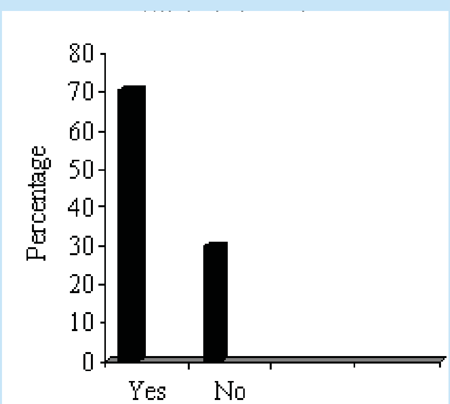

Figure 5: Pressured to Work While Fatigued

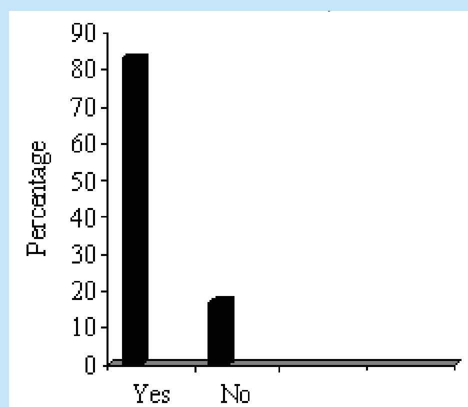

Figure 6: Is Fatigue Common in Maintenance Operations?

FATIGUE

Figure 7 asked participants to rate the safety significance of fatigue in the aviation maintenance environment. Data from survey question 18 shows the largest group of participants, 45%, indicated that they considered fatigue a “Moderate” safety concern while 39% responded in the “Serious” category.

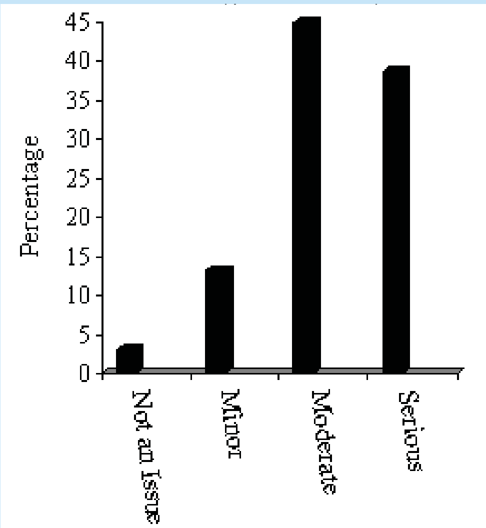

Figure 7: Is Technician Fatigue a Significant Safety Issue?

The survey collected a substantial amount of information from each of the participants, including their impressions concerning fatigue in the maintenance setting, safety, health and well being. The most significant results from the survey are presented in the following sections.

Survey question 19 asked participants if they had ever accomplished or witnessed other technicians performing procedures while in a fatigued state. With 82% reporting in the affirmative in Figure 8, this data may suggest that aircraft maintenance and repair procedures contribute to decreased performance of motor and cognitive functions resulting in impaired judgment. Even moderate fatigue levels may possibly increase the risk of employee accidents, either to themselves, co-workers or damaging an aircraft.

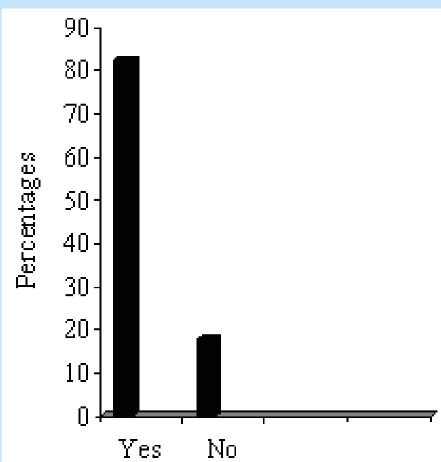

Figure 8: Working While Fatigues

Survey question 20 asked participants to recount the number of times they have been injured while working on aircraft or if they knew of instances where other AMTs had been hurt. The question did not rate severity of the injury, only frequency in the past six months. As seen in Figure 9, while 49% of participants indicated not having been hurt, 41% did report having been injured on the job once or twice due to a loss of concentration possibility related to fatigue.

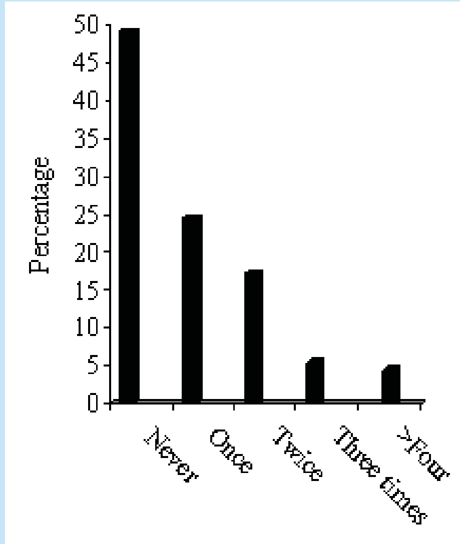

Figure 9: Fatigue Related Injury

Survey questions 21 and 22 asked participants to indicate their perceived understanding of managerial and federal efforts to educate and reduce the occurrence of fatigue in aircraft maintenance operations. The collective set of these data, represented in Figures 7 and 8 suggests that AMTs feel maintenance managers, executives and federal regulators do not perceive fatigue in aircraft maintenance operations as a major problem.

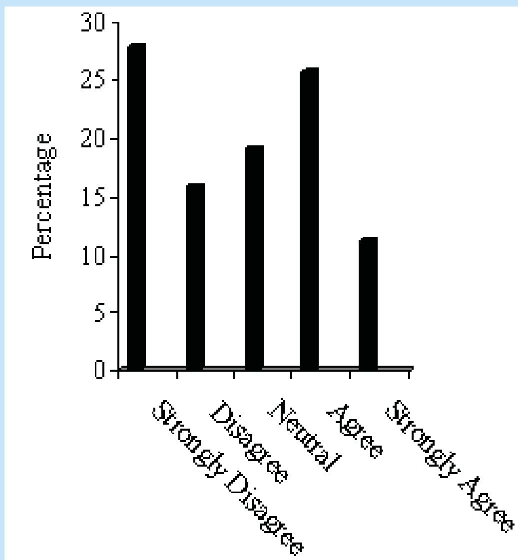

Figure 10: Employer Provided Information on Effects of Fatigue

Figure 10 indicates 43.7% of study participants either Disagree or Strongly Disagree their employer provide fatigue information and it affects on airworthiness and safety of flight, while 19% reported a neutral response to the same question.

When considered in a cooperative manner, employers, AMTs, and regulators have clear responsibilities with respect to recognizing educating and managing worker fatigue. As shown in Figure 11, a combined 42.3% of study participants responded either Disagree or Strongly Disagree to question 22, that their employer considers technician fatigue an important safety issue. An unanticipated response rate of 25.8% of participants responded in the Neutral category.

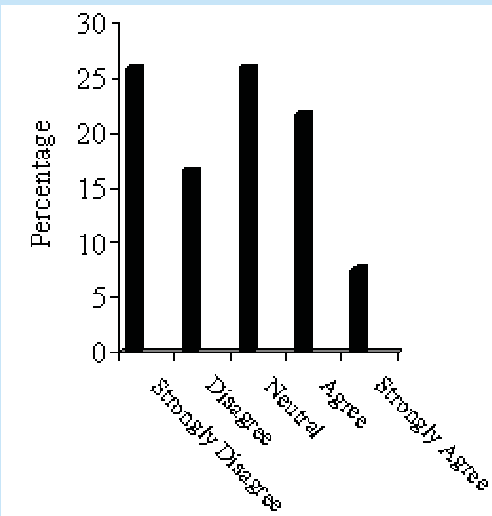

Figure 11: Employer Considers Fatigue Important Issue

Figure 12 illustrates data received from survey question 23, which asked participants if their employment situation allows AMTs to use fatigue as a cause for an excused or approved absence. The majority reported "No."

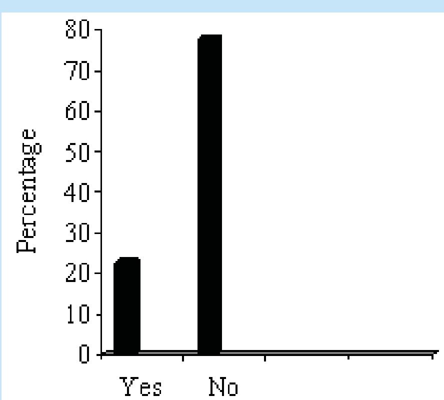

Figure 12: Fatigue as Approved Absence

DISCUSSION

The injurious effects of fatigue are not advantageous to any industry, particularly in an intensely safety sensitive industry such as aviation. In the aircraft inspection and maintenance process, the quality of workmanship and acute attention to detail has a tremendous effect on safety of flight, employee satisfaction and overall profits. Regardless of the business setting or occupation, whenever fatigue is experienced, errors increase while the quality of workmanship and productivity declines.

Overall, results from this study indicate that technicians are just as susceptible to the effects of fatigue related errors and injuries as their flight-rated counterparts and ground based controllers. Federal Aviation Regulations prescribing duty time limitations for controllers, flight crews and cabin attendants have existed for decades. While the benefits of these standards are well established, legal mandates dictating compulsory rest periods for technicians remain deficient and equivocal.

Significant discoveries in this study include 83% of participants reporting fatigue as a common occurrence in aircraft maintenance operations, while 61% reported no employee guidelines for technician rest periods. Other significant responses include 55.2% reporting irregular circadian rhythms and disruptive sleep patterns achieving only 5-6 hours of uninterrupted sleep.

A majority, 70%, felt pressured to work while fatigued and 44% indicated no formal training regarding the effects of fatigue or countermeasures. Absent federal oversight and more comprehensive rest standards, 50.8% of technicians participating in the survey reported shift periods longer than 8 hours occurring more that 11 times a month. Work place safety is also a serious concern with 50.8% reporting one or more injuries while performing maintenance tasks in a fatigued state.

CONCLUSIONS

Fatigue indicators in this study, such as pressure to work while fatigued, the frequency of fatigue in maintenance operations and a lack of managerial awareness of AMT fatigue issues suggest fatigue related episodes are experienced by AMTs at a significant rate. Study results also indicate fragmented sleep, shift work and long workdays as contributors to the dilemma.

These findings support NTSB recommendations for setting AMT work hour limits. The study also verified that federal regulators, industry executives and workers need to focus on issues related to sleepiness and alertness in aircraft maintenance operations. The development and implementation of federally mandated rest periods could be the cornerstone of an effective AMT fatigue countermeasures program. Regardless of their employment status, AMTs could benefit from regulatory protection to reduce their exposure to fatigue related incidents or injuries.

A broad based fatigue countermeasures program addressing the multiple factors that influence fatigue in aircraft maintenance operations is also critical. Specific factors that warrant additional research include: education and training, duty hours, scheduling practices, and countermeasures.

Unfortunately, some of the harmful effects of fatigue may be unavoidable in aircraft maintenance. Nevertheless, given the physical requirements and environmental concerns of aircraft maintenance operations, if sufficient regulatory oversight and training resources are made available, it should be possible to reduce the level of fatigue experienced by AMTs. For AMTs enduring the effects of fatigue, a variety of fatigue countermeasures strategies may help maintain alertness and satisfactory performance. Foremost is a strong emphasis on adequate rest guidelines along with work and rest schedules that represent a contemporary level of understanding of worker endurance.

Effective fatigue countermeasures training should also include the realization that the only effective countermeasure for fatigue is the appropriate amount of restorative rest. In addition, the only remedy for accumulated sleep debt is receiving the correct amount of uninterrupted sleep. Fatigue countermeasures should be initiated as soon as practicable to minimize fatigue related errors and safety hazards. As starting point in this effort, AMTs, executives and federal regulators must realize that a fatigued AMT is impaired until he or she receives a proper quantity of rest.

Like their flight rated counterparts and ground based controllers, AMTs are not machinery expected to operate for extended periods and varying schedules. Their internal biological cycles coupled with the physical need for sleep must be considered when implementing shift schedules and extensive maintenance procedures. The survey confirmed a work force that is highly skilled and experienced. But neither of these traits can annul the physical need for sleep and rest. As long as twenty-four hour maintenance operations are required to meet demanding aircraft utilization rates and flight schedules, a through understanding of the effects of shift work, sleep loss, irregular circadian rhythms and less than comfortable physical environments will be crucial to AMT safety and productivity.

Since the beginning of powered flight, fatigue has become perhaps the most frequent medical complaint reported by aerospace workers. However, the introduction of advanced technology aircraft in both scheduled and corporate aircraft sectors are likely to continue and possibly increase the occurrence of fatigue events experienced by AMTs. human performance in safety sensitive environments such as aircraft maintenance is in large measure a product of proper facilities, training and the realization of endurance factors. Therefore, technicians, executives and regulators must be prepared to effectively deal with fatigue to sustain productivity, safety, and personal well being.

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APPENDIX A

1. Introduction

AIRCRAFT MAINTENANCE TECHNICIAN FATIGUE SURVEY

The Aerospace Department at Middle Tennessee State University (MTSU) is conducting a research study of fatigue and alertness experienced by federally certificated aircraft maintenance technicians working various shifts and job functions. The purpose of this study is to determine the frequency and severity of fatigue across a board spectrum of aircraft inspection, maintenance and repair operations. The study will also attempt to examine the effectiveness of individual, managerial and federal regulatory efforts to reduce fatigue and related errors encountered in aircraft inspection and repair functions.

The information you provide is entirely voluntary and your responses will not be identified in any way beyond non-identifiable descriptive information such as age, gender, federal ratings and experience. There are no known risks if you choose to participate, nor will you be penalized if you decide not to participate. There are no rewards (monetary or otherwise) available to those who choose to participate. You may withdraw from the survey at any time by clicking on the "Exit this survey" link or closing your web browser. By completing this on-line survey, you are voluntarily agreeing to participate.

This survey will be completed by aircraft maintenance technicians employed in a variety of aircraft inspection and repair operations. The questionnaire should take approximately 10 minutes to complete.

MTSU IRB #07-129, Exempt Research

If you have any questions concerning your rights as a research subject, please contact:

Ms. Tara Prairie, Compliance Officer
Office of Research and Sponsored Programs
Middle Tennessee State University
MTSU P.O. Box 134
Murfreesboro, TN 37132
Tel: (615) 494-8918
email: compliance@mtsu.edu

If you have any questions about this study, please contact:

Joe Hawkins, Assistant Professor
Department of Aerospace
Middle Tennessee State University
MTSU P.O. Box 67
Murfreesboro, TN 37132
Tel: (615) 904-8360
email: jhawkins@mtsu.edu

2. Survey Directions

This survey contains 23 questions. The questions are a combination of "Yes" or "No" and multiple choice. Most questions require a response before moving to the next question.

Your responses will remain anonymous; neither you nor the employer will be identified in the study results. IP addresses are not recorded, stored or associated in any way with this on-line survey and are blocked by the SurveyMonkey collector to remain anonymous to the researcher.

When you have completed the survey, please click "Done" at the bottom of the page.

3. General

1. Gender:

- ☐ Male
- ☐ Female

2. Age

- ○ 18-24
- ○ 25-44
- ○ 45-64
- ○ 65 or older

3. My experience as a certificated Airframe and/or Powerplant Mechanic or Repairman is:

- ○ 5 years or less
- ○ 6-10 years
- ○ 11-15 years
- ○ 16-20 years
- ○ More than 20 years

4. What certificates/ratings do you currently hold? (Check all that apply)

- ☐ Airframe
- ☐ Powerplant
- ☐ Repairman
- ☐ Inspection Authorization

5. Under which of the following FAR Part(s) do you or your facility operate? (Check all that apply)

- ☐ Part 25
- ☐ Part 43/65
- ☐ Part 121
- ☐ Part 135
- ☐ Part 145 (includes Foreign Repair Stations)

4. Normal Day

Please give your best answer to the following questions.

6. Do you have trouble falling to sleep on a regular basis?

- ○ Yes
- ○ No

7. On average, how long do you sleep uninterrupted each night?

- ◯ 0-4 hours
- ◯ 5-6 hours
- ◯ 7-8 hours
- ◯ 9 or hours

8. In the past month, how often has work related anxiety interfered with your sleep?

- ◯ Often
- ◯ Occasionally
- ◯ Seldom
- ◯ Rarely
- ◯ Never

9. When you awake, do you ever feel fatigued or lacking in sleep?

- ◯ Often
- ◯ Occasionally
- ◯ Seldom
- ◯ Rarely
- ◯ Never

5. DUTY

Please answer the following work shift and duty time questions as accurately as possible. Use local time settings.

10. My normal work shift begins:

- ☐ 5 AM to 12 Noon
- ☐ 12 Noon to 5 PM
- ☐ 5 PM to Midnight
- ☐ Midnight to 5 AM

11. The number of days that I normally work in a row without a day off are:

- ◯ 3 or less days
- ◯ 4-5 days
- ◯ 6-7 days
- ◯ 8-9 days
- ◯ 10 or more days

12. In past month, I worked more than eight (8) hours a day:

- ◯ 0-1 times
- ◯ 2-4 times
- ◯ 5-7 times
- ◯ 8-10 times
- ◯ 11 or more times

13. Does your employer have a written policy or guidelines concerning rest periods for technicians?

- ◯ Yes
- ◯ No

14. Have you ever been asked or felt pressured to work while you were fatigued?

- ◯ Yes
- ◯ No

6. FATIGUE

15. Are you required to arrive at work before your shift begins for job assignments, task briefings, training or other employer activities?

- ☐ Yes
- ☐ No

16. If you answered "Yes" to #15, how much earlier do you report to work?

- ☐ 15 minutes or more
- ☐ 30 minutes or more
- ☐ 1 hour

Other (please specify)

17. In your opinion, is technician fatigue a common occurrence in aircraft maintenance operations?

- ◯ Yes
- ◯ No

18. In your opinion, when technician fatigue occurs, how significant a safety issue is it?

☐ Not an issue ☐ Minor ☐ Moderate ☐ Serious

19. In the past six (6) months, have you accomplished or witnessed other technicians performing aircraft inspection or maintenance procedures while fatigued?

- ◯ Yes
- ◯ No

7. FATIGUE

20. In the last six (6) months, how many times have you or other technicians been injured while working on or around aircraft due to a loss of concentration that may be related to fatigue?

- ☐ Never
- ☐ Once
- ☐ Twice
- ☐ Three times
- ☐ Four or more times

21. I have been given information related to fatigue and its effects on airworthiness and safety.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly Agree

22. My employer believes that technician fatigue is an important safety issue in aircraft maintenance operations.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly Agree

23. Does your employer allow technicians to use fatigue as an approved absence?

- ◯ YES
- ◯ NO

Today's Special: There is No "I" in Team

One School's Effort to Address the Psychosocial Element of Human Factors

By Tiffany M. Hall

The aviation maintenance industry is not just about nuts and bolts. As human factors have assumed a more prominent role in aviation maintenance, it has become increasingly important that newly graduated and licensed aviation maintenance technicians (AMT) enter the workforce prepared for the human side of this industry. For educators preparing graduates for careers in aviation maintenance, it may be challenging to convince students excited about going out into the hangar and gaining hands on experience to direct their attention to something that they may not immediately perceive as having relevance to aircraft repair. This article addresses the importance of appropriate interpersonal skills in the industry and shares one school's strategy to include human factors instruction, specifically the psychosocial element, in a non-threatening, creative, and uniquely engaging way.

Human factors in aviation are those things that affect the maintenance process (Gramopadhye & Drury, 2000; Wurmstein, Shetler & Moening, 2004). More specifically, it refers to the factors affecting the interaction between the AMT and the aircraft. Developed by the Federal Aviation Administration (FAA) in response to the findings of an investigation into the 1988 Aloha Airlines incident involving the structural failure of the fuselage of a Boeing 737, human factors, also referred to as the "dirty dozen," include complacency, lack of communication, lack of knowledge, lack of resources, distraction, lack of teamwork, fatigue, pressure, stress, lack of assertiveness, lack of situational awareness, and norms (Gramopadhye & Drury, 2000). Wurmstein et al. (2004) clustered the factors into categories referred to as the Five P's: physical, physiological, psychological, psychosocial, and pathological. Because aviation maintenance is a team effort, the psychosocial aspect is of great importance when considering the human factors.

The ability to interact and work cooperatively with others is becoming of increased value in the aviation maintenance industry. While other sectors of the workforce have become increasingly diverse, the aviation maintenance industry has been slow to change. Citing Phillips, Head (2001) reported that in 1999, 98.62% of AMTs were male. Although the face of aviation maintenance continues to be male and predominantly Caucasian, there are a number of programs aimed at diversifying the aviation maintenance industry (Head, 2001; Williams & Rhoades, 2006). In 1998, the U.S. Department of Education partnered with the National Academy of Sciences to develop a set of dimensions to address the challenge of improving diversity in aviation (U.S. Department of Education, 1998). Those dimensions are as follows:

> *Dimension 1: Efforts must be made to develop the interest of individuals from underrepresented groups in undertaking aviation careers.*
>
> *Dimension 2: There must be equal opportunities for minorities and women to develop the basic academic competencies to successfully pursue aviation careers if they choose.*
>
> *Dimension 3: Any remaining barriers must be addressed that formally or informally have a disproportionate effect on the ability of minorities and/or women to pursue aviation careers if they have the interest and the basic academic competencies.* (U.S. Department Education, 1998, pp. 2-4).

As a result of the publication of the aforementioned dimensions, as well as a predicted shortage of qualified and licensed AMTs, many AMT schools actively recruit minorities and females. Schools dangle carrots such as financial assistance programs to attract such students and provide various means of student support once enrolled to ensure retention.

While the aviation industry may not currently reflect the race and gender landscape of America's overall workforce, diversity remains an issue within the field due to such differences as personality, motivation, and age. Appropriate interaction with supervisors, the ability to bridge the generation gap among baby boomers, generation X-ers, and generation Y-ers, and working with a personality opposite or an irritating co-worker are all desirable social skills for today's aviation maintenance technician (AMT).

Appropriate and effective interaction with others is essential to the work performance of the AMT. Troubleshooting requires technicians to work cooperatively colleagues and supervisors to resolve what may be a potentially life threatening problem. Without the social skills to work interdependently as a unit, the troubleshooting process may become a dreaded task wherein those involved hastily rush toward completion in an effort to escape those managers or co-workers perceived as intolerable. Such feelings have the capability to adversely affect workplace communication, which may lead to incomplete or incorrect information when attempting to resolve a problem or when transferring reports from one shift or crew to another—all potentially fatal errors.

Rodney Pinner, Career Services Coordinator at the Aviation Institute of Maintenance (AIM) in Norfolk, Virginia, has taken a unique approach to address the psychosocial element of human factors in the aviation maintenance industry. In April 2007, Pinner established the CD (career development) Café at AIM Norfolk in response to the looming shortage of qualified AMTs, the retention, graduation, and placement requirements established by the school's accrediting body, and the call for an increased emphasis on human factors in the AMT curriculum. Pinner believed that it would be a fun way to put a fresh spin on topics that some students may view as mundane and irrelevant. He knew that to be successful, the CD Café had to capitalize on some of the best practices in adult education. As indicated by Knowles (1998), adult learners prefer learner-centered environments, learn readily from peers, they possess a large reservoir of life experiences to bring to and support new learning, and flourish when their experiences and knowledge are acknowledged. These generalizations have all influenced the design of CD Café. The hook is the opportunity to enjoy food (provided by students) and fellowship in a relaxed environment where participants are comfortable sharing ideas and asking questions. Students at the Norfolk campus are encouraged to attend the CD Café during the 30-minute lunch period. Pinner posts signs announcing the session time, location, and topic one day prior to remind students to bring lunch on the following day instead of making plans to leave campus for lunch. Two sessions are held each Wednesday so that students in the day and evening programs can attend. From day one, Pinner has been serving it up hot. Billed as today's special, topics have included *First Impression*, *How to Play the Interview Game*, and *Different Strokes for Different Folks*. After a brief presentation of the topic and associated handouts by Pinner, participants engage in a loosely moderated discussion of the topic while they partake of their lunch or dinner. Students ask questions of Pinner and other participants and frequently recount personal work experiences as they relate to the topic. AIM Norfolk faculty members occasionally attend to share insights, as well as their personal experiences in the aviation maintenance industry. Although not an intended feature of the CD Café, the interaction between students and faculty within the sessions has created informal mentorships. Mentorship programs have been proven to increase retention among students, particularly minorities and females, and to improve overall student performance (Daloz, 1999; Scott & Homant, 2007).

In surveys, student participants have indicated satisfaction with the CD Café and many commented that the CD Café, along with Pinner, has positively influenced their experiences at the Norfolk campus. Although the program is not a part of the school's official curriculum and course offerings, students consider CD Café to be relevant to the training programs at AIM Norfolk and to what will be expected of them in the workplace. Wayne Smith, a student since January 2007, has completed the 13-week CD Café program and has earned his CD Café A&P (attitude and professionalism) license. However, he continues to attend because he sees great benefit in the workshops and all that Pinner has to share. Smith, stated, "Appropriate interpersonal skills are definitely important in the workplace. Relationships with others would affect the way we all work together as a team. If you can't work well with others and work as a unit, then you may as well start looking for another job because you have to be able to work together to troubleshoot well. It could make all the difference between life and death." Edward Kweri, a student from Sudan, is near completion of his degree program and expects to work in New York after graduation. He referred to the sessions as being helpful not only for employment, but for life itself because traits such as understanding and self-discipline are useful in situations outside of work. Kweri asserted, "The CD Café has helped me to further realize the importance of courtesy and discipline on the job. Teamwork is always necessary for the work environment, but in aviation maintenance it is even more critical. The safety of others is at stake. The more we [AMTs] work as a team, the more productivity and accuracy is increased." Citing the benefits of sessions focusing on seeking employment in the aviation maintenance field, Brandon Bates shared, "This is a new field for me. These classes have really helped me think about how I present myself to a company, which I've never had to do before because I always got jobs through friends." Student responses such as these indicate the CD Café's ability to meet the needs of students hoping to gain useful tools in navigating the aviation maintenance job market, as well as insights that will assist them in finding success in that field.

Exposure to diverse ideas shared by and among diverse people has been a key component of the CD Café. The program's primary goal is to address human factors in aviation maintenance, specifically as related to group dynamics. While attending a 30-minute session, participants can expect to hear opinions completely contradictory to their own, to have their thoughts and ideas challenged, to cultivate skills that will improve employability, and to build relationships among colleagues and school personnel. Such experiences increase tolerance and allow participants to develop the ability to consider issues from multiple perspectives and to practice appropriate and effective communications in social settings consisting of diverse groups, all skills critical when working cooperatively with colleagues and supervisors in the workplace.

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The Importance of Introducing New and Advanced Materials in Technology Education

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ABSTRACT
Incorporating new, advanced materials into a curriculum is always a challenging task. It requires a significant commitment of time, equipment, and resources if the new area is to be treated effectively. Clearly, though, the charge of technical and engineering technology education is to prepare graduates to support new technology, and advances in aircraft design in particular rely heavily on the development of new materials which exhibit increased strength and decreased weight. Corrosion resistance and repairability are also fundamental if these new aircraft are to be economically supported in the field. Metal matrix composites fall in the category of advanced materials. As these materials become increasingly common in aircraft applications, it is incumbent upon technology education to incorporate these topics and, eventually, practical projects into the curriculum. The methods and philosophy followed by the Aeronautical Engineering Technology program in the materials area will serve as background for this educational effort now underway. Technical information on MMCs is provided for the the reader to view as an introduction to the topic.

INTRODUCTION
New and advanced materials offer both important educational opportunities and time-consuming challenges for Part 147 and engineering technology programs. In order for aviation technology students to be properly prepared for the workplace, the curriculum must be current and relevant, and this demands that instructors stay abreast of emerging technologies and applications. Materials related to this topic were presented at the Annual ATEC 2008 Conference. Those present expressed interest in the topic and its implications for technology education. The materials area is often very challenging for the development of new coursework due to the fact that specific applications in the aerospace industry are often clouded in secrecy, making it difficult to bring real world examples to the laboratory. New materials tend to be quite expensive, as well, which limits the size and number of projects that may be economically introduced in the laboratory. In many cases, new tools are also required to work the material, and that material may have special storage requirements. The expense and commitment of these and other resources may be considerable. On the positive side, the educational benefits and engagement opportunities that arise from the development of related coursework are considerable. The instructor charged with development of a unit of instruction or a teaching plan must have a fundamental understanding of how it fits into the overall curriculum. He or she must determine the level of knowledge and skill that is important for the students to achieve, and then target the educational objectives and the overall development effort accordingly.

These issues are particularly important for the upper division materials courses in the Aeronautical Engineering Technology (AET) program at Purdue University. Aircraft materials and processes is an important area of concentration in this ABET curriculum, therefore it is vital to consistently incorporate cutting edge technology into these junior and senior level courses. AET is a four-year, Bachelor of Science program which includes a core curriculum of FAA-approved Part 147 coursework, and a strong emphasis on engineering technology. An initiative underway by the faculty to obtain ABET accreditation for this program is nearing conclusion. This will be the first program of its kind, combining an approved Part 147 curriculum together with engineering technology, to be so accredited. ABET is the foremost accrediting body in academia for programs in engineering, technology, science, and computing.

These upper division materials courses include a significant engineering focus on material properties and related manufacturing considerations. This material emphasis continues into other upper division courses including AT 385, Design Support Analysis, and AT 496 / 497, which are the companion capstone courses in Design Research Proposal and the Senior Project. As these instructors incorporate new materials and technologies into their coursework, knowledge of the coordinated curriculum is critical for determining the appropriate teaching level. Specifically, as it relates to this discussion, ABET requires that programs accredited under Aeronautical Engineering Technology criteria must demonstrate that graduate have technical expertise in engineering materials and strength of materials. Program graduates must also have technical expertise in manufacturing processes, vehicle design and modification, and system life cycle relating to the manufacture and maintenance of aeronautical/aerospace vehicles and their components (ABET). Clearly, these accreditation requirements play a major role in the decision-making process as instructors design new coursework to include these advanced materials.

The formal vision of this evolving program is that the Aeronautical Engineering Technology program will produce graduates who have hands on skills with aerospace vehicle systems, the demonstrated ability to think critically and manage projects, and who have a broad academic education. Program goals are that AET graduates will be able to be successful in entry-level positions at aerospace manufacturers in engineering positions such as project, manufacturing, liaison, design, retrofit or tooling, or technical support; direct maintenance and vehicle operations; and entry level positions in the airline or corporate aviation industry in areas such as, airline reliability engineering or maintenance planning. It is further expected that program graduates will be ready and qualified to assume positions of management and leadership in the aerospace industry in the two to five year post graduate timeframe.

While accreditation does provide a set of imposing criteria for a program, the vision of the faculty should truly establish the direction for curriculum design. As instructors incorporate new materials and technologies into individual courses, the top-down view from these perspectives is crucial. At the same time, unit instructional design should flow in a meaningful pattern that may be best studied in the context of the individual courses under development.

METAL MATRIX COMPOSITES: AN INTRODUCTION

The following technical material is taken largely from two sources: The *OSHA Technical Manual* and the *Composite Materials Handbook,. Volume 4,* published by the Department of Defense. These two sources, both available online, provide considerable technical information, which the authors found to be very useful while investigating the subject matter for inclusion in the curriculum. For the reader who is new to the subject of MMCs, this material may be useful, and these two sources are highly recommended as consideration is given to the introduction of these materials to an existing curriculum.

The composites industry in the United States includes three manufacturing areas: Polymers, metals, and ceramics (OSHA 1995). Composites are classified according to their matrix phase. There are:

(a) polymer matrix composites (PMC's),

(b) ceramic matrix composites (CMC's), and

(c) metal matrix composites (MMC's).

Materials within these categories are often referred to as "advanced" if they combine the properties of high strength and high stiffness, low weight, corrosion resistance, and in some cases special electrical properties. This combination of properties makes advanced composites very attractive for aircraft and aerospace structural parts.

Advanced composites have been identified as an important growth sector in U.S. manufacturing. This identification has led to more use of these materials in existing facilities as well as an increase in the number of advanced composites manufacturing locations. Field staff may expect to encounter composites more frequently in the course of their assignments. At the same time, much of the technology is new and not presented formally in secondary or undergraduate education, therefore, new hires first entering the industry have neither technical knowledge, nor hands-on experience with these materials.

Information is presented here on the technology as practiced in current operations. The technology of advanced composites manufacture is continually evolving, and field personnel will learn here what to expect in these processing facilities in the way of materials handled, manufacturing methods, machinery, potential worker exposures, and other relevant health and safety information.

While aerospace is the predominant market for advanced composites today, the industrial and automotive markets will increasingly see the use of advanced composites, largely due to the weight and corrosion resistance advantages these materials possess. . At present, both manual and automated processes are employed in making advanced-composite parts, butas automated processes become more predominant, the costs of advanced composites are expected to decline rapidly, allowing more widespread use of these materials in electronic, machinery, and surface transportation equipment. Currently, suppliers of advanced composite materials tend to be larger companies capable of conducting the research and development necessary to provide the high-performance resin systems used in this segment of the industry. End-users also tend to be large, and many are in the aircraft and aerospace businesses.

MMCs differ from other composite materials in several ways (DoD 2002). Some of these general distinctions are as follows:

1. The matrix phase of an MMC is either a pure or alloy metal as opposed to a polymer or ceramic.

2. MMCs evidence higher ductility and toughness than ceramics or CMCs, although they have lower ductility and toughness than their respective unreinforced metal matrix alloys.

3. The role of the reinforcement in MMCs is to increase strength and modulus, as is the case with PMCs. The main purpose of reinforcement in CMCs is generally to provide improved damage tolerance.

4. MMCs have a temperature capability generally higher than polymers and PMCs but less than ceramics and CMCs.

5. Low to moderately reinforced MMCs are formable by processes normally associated with unreinforced metals.

OVERVIEW OF MATRIX MATERIALS

Metals are extremely versatile engineering materials. A metallic material can exhibit a wide range of readily controllable properties through appropriate selection of alloy composition and thermomechanical processing method. The extensive use of metallic alloys in engineering reflects not only their strength and toughness but also the relative ease and low cost of fabrication of engineering components by a wide range of manufacturing processes. The development of MMCs has reflected the need to achieve property combinations beyond those attainable in monolithic metals alone. Thus, tailored composites resulting from the addition of reinforcements to a metal may provide enhanced specific stiffness coupled with improved fatigue and wear resistance, or perhaps increased specific strength combined with desired thermal characteristics (e.g., reduced thermal expansion coefficient and conductivity) in the resulting MMC. However, the cost of achieving property improvements remains a challenge in many potential MMC applications.

MMCs involve distinctly different property combinations and processing procedures as compared to either PMCs or CMCs. This is largely due to the inherent differences among metals, polymers and ceramics as matrix materials and less so to the nature of the reinforcements employed. Pure metals are opaque, lustrous chemical elements and are generally good conductors of heat and electricity. When polished, they tend to reflect light well. Also, most metals are ductile but are relatively high in density. These characteristics reflect the nature of atom bonding in metals, in which the atoms tend to lose electrons; the resulting free electron “gas” then holds the positive metal ions in place. In contrast, ceramic and polymeric materials are chemical compounds of elements. Bonding in ceramics and intramolecular bonding in polymers is characterized by either sharing of electrons between atoms or the transfer of electrons from one atom to another. The absence of free electrons in ceramics and polymers (no free electrons are formed in polymers due to intermolecular van der Waals bonding) results in poor conductivity of heat and electricity, and lower deformability and toughness in comparison to metallic materials.

ROLE OF MATRIX MATERIALS

The choice of a matrix alloy for an MMC is dictated by several considerations. Of particular importance is whether the composite is to be continuously or discontinuously reinforced. The use of continuous fibers as reinforcements may result in transfer of most of the load to the reinforcing filaments and hence composite strength will be governed primarily by the fiber strength. The primary roles of the matrix alloy, then, are to provide efficient transfer of load to the fibers and to blunt cracks in the event that fiber failure occurs, and so the matrix alloy for a continuously reinforced MMC may be chosen more for toughness than for strength. On this basis, lower strength, more ductile, and tougher matrix alloys may be utilized in continuously reinforced MMCs. For discontinuously reinforced MMCs, the matrix may govern composite strength. Then, the choice of matrix will be influenced by consideration of the required composite strength and higher strength matrix alloys may be required.

Additional considerations in the choice of the matrix include potential reinforcement/matrix reactions, either during processing or in service that might result in degraded composite performance; thermal stresses due to thermal expansion mismatch between the reinforcements and the matrix; and the influence of matrix fatigue behavior on the cyclic response of the composite. Indeed, the behavior of MMCs under cyclic loading conditions is an area requiring special consideration. In MMCs intended for use at elevated temperatures, an additional consideration is the difference in melting temperatures between the matrix and the reinforcements. A large melting temperature difference may result in matrix creep while the reinforcements remain elastic, even at temperatures approaching the matrix melting point. However, creep in both the matrix and reinforcement must be considered when there is a small melting point difference in the composite.

FORMS OF MATRIX MATERIALS

Metals are routinely available in a wide variety of product forms intended for subsequent manufacturing operations. These forms include re-melting stock for casting, wrought materials including wire, foil, sheet, bar, plate, a wide variety of extruded shapes, and powder. Many of these different forms are employed in the manufacturing of MMCs. Melt processing methods such as liquid metal infiltration require re-meltable compositions. Foil/fiber/foil methods require matrix foil in appropriate thicknesses (typically 0.1 mm or 0.004 inch); in general, foil refers to a flat rolled product of thickness less than 0.012 inch (0.3 mm). Such thickness is readily attainable by rolling of many ductile matrix alloys but may require special rolling methods for less workable alloys. Most metals can be reduced to powder by a variety of methods.

TYPES OF MATRIX MATERIALS

Many MMC applications involve considerations other than strength alone - e.g., electrical contacts - and so there are corresponding requirements for many types of matrix materials. Pure metals generally are soft and weak as well as being high in electrical and thermal conductivity. This is because the factors which result in easy plastic deformation and low strength with high ductility also allow for ready motion of free electrons and, therefore, high electrical and thermal conductivity. Thus, applications requiring high thermal or electrical conductivity combined with high strength and resistance to wear, e.g., contact points, may employ pure metal matrices with ceramic reinforcements.

In recent years there has been a growing emphasis on alloy compositions near to those of certain intermetallic compounds such as Titanium Aluminides. Such intermetallic compounds and the alloys based on them often exhibit attractive combinations of low density, high melting point and high strength at elevated temperatures. On the other hand, the ductility of such compounds is generally poor since bonding is often covalent or ionic in character rather than metallic.

Matrix alloys are also classified according to melting temperature. Exceptionally high melting temperatures such as found with Mo, Nb, and W are termed refractory, meaning difficult to melt. Metals such as Fe, Ni, and Cu are considered to exhibit ordinary melting behavior while Al and Mg are relatively lower temperature melting materials.

Many different metals have been employed in MMCs and the choice of matrix material provides the basis for further classification of these composites. Alloy systems including aluminum, copper, iron (steels), magnesium, nickel, and titanium have been utilized as matrices and each of these are discussed further.

ALUMINUM

A wide range of aluminum alloys in various forms have been incorporated in MMCs. The density of most aluminum alloys is near that of pure aluminum, approximately 0.1 lb/in3 (2698 kg/m3). Pure aluminum melts at 1220°F (660°C); this relatively low melting temperature in comparison to most other potential matrix metals facilitates processing of Al-based MMCs by solid state routes, such as powder metallurgy, and by casting methods. Aluminum alloys are broadly classified as either wrought or cast materials; furthermore, many wrought compositions are also available in powder form. The term "wrought" indicates that the material is available primarily in the form of mechanically worked products such as rolled sheet, plate or foil, various extruded shapes, tubing, forgings, wire, rod, or bar. The ready availability of aluminum alloy foils and relatively low processing temperatures allowed the foil-fiber-foil method to be successfully developed and utilized during the 1970s to produce aluminum alloys reinforced with continuous boron or SiC-coated boron fibers for aerospace applications. The 6061 Al-Mg-Si alloy in foil form was employed in many instances and this same alloy composition has also been used in cast form as the matrix in continuously reinforced Al-graphite composites. Many wrought aluminum alloy compositions are well suited for extrusion and most discontinuously reinforced aluminum (DRA) MMCs, whether initially consolidated via powder metallurgy or casting methods, are processed in this manner. Aluminum alloys intended for use in production of castings are generally available as ingots of varying size or in other forms suitable for re-melting. Applications of such cast materials have included the production of cast components using DRA, with stirring to suspend particles in the liquid metal prior to casting and solidification of the article.

The designation schemes for both wrought and cast alloys are based on the major alloying additions. Wrought alloys are designated by four digits while cast compositions are designated by three digits (Table 1). Further details of compositions are available from many sources. Both wrought and cast alloy compositions may be further classified according to the method of obtaining mechanical properties: heat treatable or non-heat treatable. Heat treatable refers to alloys that can be strengthened by thermal treatment. Wrought alloys of the 2XXX, 6XXX and 7XXX series are generally heat treatable and those that contain major additions of lithium (e.g., some 8XXX alloys) are also heat treatable. Typical heat treatment operations may include solution heat treatment, quenching in a liquid medium and subsequent aging. A temper designator is appended to the alloy designation to describe the resulting condition of heat treatment. Thus, -T4 refers to material allowed to naturally age at room temperature following solution heat treatment and quenching, while -T6 describes artificial aging to the peak strength. Additional digits may be used to indicate further details of processing such as straightening operations. Further details of heat treatments and their effect on properties are available in numerous References. The addition of reinforcements (especially particles and whiskers) has been shown to have a significant effect on the aging response of the matrix composition for many DRA MMCs. The aging response may be either accelerated or retarded and the effect is both material and process specific. For this reason the aging treatment for a MMC with a heat treatable matrix alloy may differ significantly from that for the unreinforced matrix. Furthermore, most wrought alloys contain minor alloy additions. For example, Zr is added to various alloys to control recrystallization during hot working. However, the presence of reinforcing particles in an MMC may also aid in grain refinement and obviate the need for some of the minor additions often found in wrought alloys.

Designation		Major Alloying Element(s)
Wrought	Cast	
1XXX	1XX	None
2XXX	2XX	Cu
3XXX	----	Mn
	3XX	Si + Mg; Si +Cu; Si + Mg +Cu
4XXX	4XX	Si
5XXX	5XX	Mg
6XXX	----	Mg + Si
7XXX	7XX	Zn
8XXX	----	Other than above
	8XX	Sn

TABLE 1 *Designations for Aluminum Alloys (Aluminum Association - AA and American National Standards Institute - ANSI).*

Non-heat treatable alloys are those that are not appreciably strengthened by heat treatment. The strength of the material is determined by the presence of alloying elements present in solid solution and by the extent of any cold working. Wrought alloys of the 1XXX, 3XXX, 4XXX and 5XXX series are generally non-heat treatable. The appended temper designators for these alloys are generally either -O, referring to a fully annealed and softened condition, or -H (with additional digits). The H refers to the use of plastic deformation, typically by cold rolling, to strengthen the material, and the additional digits describe the extent of strain hardening and related annealing treatments to control strength, ductility and susceptibility to stress corrosion. Temper designators similar to those employed with wrought heat treatable alloys are employed with heat treatable (2XX, 3XX, 7XX and 8XX series) casting alloys. Since castings will not experience appreciable mechanical deformation in manufacture, the non-heat treatable 1XX, 4XX and 5XX series cast aluminum alloys are either designated -F (as-cast) or -O (cast and annealed for stress relief). Aluminum-silicon alloys (3XX and 4XX series) are predominant among cast aluminum alloys because they generally exhibit high fluidity when molten and, thus, are well suited for complex shapes and thin sections. Such fluidity is an important consideration in selection of matrix compositions for cast MMCs where, for example, it may be necessary to completely fill the mold volume. The presence of silicon in aluminum significantly lessens the tendency of aluminum to react chemically and reduce SiC and form Al4C. This latter compound severely embrittles SiC-reinforced Al MMCs even when present in small quantities. For this reason cast aluminum MMCs incorporating SiC particles as reinforcements utilize alloys such as AA 359 as the matrix material. Alternatively, SiC can be incorporated into aluminum alloys by powder metallurgy methods; lower processing temperatures in the solid state reduce the tendency to formation of Al4C and this affords a wider range of choice of matrix composition. Many AA3XX die casting alloys employed in MMCs also contain an iron addition (approximately one weight percent) to reduce the reaction between molten aluminum and steel die surfaces.

TITANIUM

Titanium matrix composites have been successfully produced from a wide range of beta, alpha-beta and alpha-phase titanium alloy compositions. Since titanium alloys range in density from approximately 0.18 lb/in3 (4317 kg/m3), they are typically 60% higher in density than aluminum alloys and 40% lower in density than low alloy steels at strength levels comparable to annealed steel. Titanium alloys typically maintain good structural properties and oxidation resistance at temperatures up to 315°C (600°F). Since these alloys will provide higher matrix property contributions to a composite system than previously observed in continuous fiber reinforced aluminum composites, there is a greater interest in specific alloy selection.

Although titanium alloys are available in most wrought product forms, its high (approximately 3200°F (1750°C)) melting temperature and work hardening characteristics make some alloys more difficult to process than others. In general, beta-phase alloys can be mechanically worked to higher reduction ratios than alpha-beta alloys, while alpha-beta alloys exhibit greater elevated temperature strength retention. In addition, titanium is a highly reactive element and, therefore, difficult to handle and process at elevated temperatures. Titanium melting/pouring and rapid solidification operations must be performed in vacuum environments.

Titanium alloys are typically identified by their major alloying constituents (e.g., Ti-6Al-4V, Ti-15V-3Cr- 3Al-3Sn), although several specific alloys have registered trade names (e.g., Timetal-21, Ti-1100). The most common alloys used in titanium compositing have been Ti-6-4, Ti-15-3-3-3, Ti-6-2-4-2 and Timetal-21. There has been significant interest in a variety of titanium aluminide alloys, including alpha-2, super alpha-2, gamma, and most recently orthorhombic alloys. These alloys offer higher elevated temperature strength, creep strength, and microstructural stability and are attractive for some gas turbine engine applications, however, low ductility and low tolerance for interstitial contaminants makes processing much more difficult.

REINFORCEMENT MATERIALS

Reinforcement materials in MMCs are discrete fibers or second phase additions to a metallic matrix that result in a net improvement in some properties, typically an increase in strength and/or stiffness. Most often reinforcement materials for MMCs are ceramics (oxides, carbides, nitrides, etc.) which are characterized by their high strength and stiffness both at ambient and elevated temperatures. Examples of common MMC reinforcements are SiC, Al2O3, TiB2, B4C, and graphite. Metallic reinforcements are used less frequently.

TYPES OF REINFORCEMENT

Reinforcements can be divided into two major groups: (a) particulates or whiskers; and (b) fibers. Fiber reinforcements can be further divided into continuous and discontinuous. Fibers enhance strength in the direction of their orientation. Lower strength in the direction perpendicular to the fiber orientation is characteristic of continuous fiber reinforced MMCs. Discontinuously reinforced MMCs, on the other hand, display more isotropic characteristics.

ROLE OF REINFORCEMENT

The role of the reinforcement depends upon its type in structural MMCs. In particulate and whisker reinforced MMCs, the matrix is the major load bearing constituent. The role of the reinforcement is to strengthen and stiffen the composite through prevention of matrix deformation by mechanical restraint. This restraint is generally a function of the ratio of interparticle spacing to particle diameter. In continuous fiber reinforced MMCs, the reinforcement is the principal load-bearing constituent. The metallic matrix serves to hold the reinforcing fibers together and transfer as well as distribute the load. Discontinuous fiber reinforced MMCs display characteristics between those of continuous fiber and particulate reinforced composites.

Typically, the addition of reinforcement increases the strength, stiffness and temperature capability while reducing the thermal expansion coefficient of the resulting MMC. When combined with a metallic matrix of higher density, the reinforcement also serves to reduce the density of the composite, thus enhancing properties such as specific strength.

REINFORCEMENT COATINGS

ROLE OF COATINGS

In many MMCs, it is necessary to apply a thin coating on the reinforcements prior to their incorporation into the metal matrix. In general, coatings on the fibers offer the following advantages:

1. Protection of fiber from reaction and diffusion with the matrix by serving as a diffusion barrier

2. Prevention of direct fiber-fiber contact

3. Promotion of wetting and bonding between the fiber and the matrix

4. Relief of thermal stresses or strain concentrations between the fiber and the matrix

5. Protection of fiber during handling

In some instances particulates are coated to enhance composite processing by enhancing wetting and reducing interfacial reactions.

TYPES OF COATINGS

Given the major role of coatings, there are several techniques available for the deposition of thin coatings on long fibers and, to a much lesser extent, on short fiber and particulate reinforcement. One such process is chemical vapor deposition (CVD). In this process, hot fiber is traversed through a reaction zone in which a vaporized species either decomposes thermally or reacts with another vapor so as to form a deposit on the fiber. Sometimes, the deposition process is enhanced by generating an electric discharge plasma (plasma-assisted CVD). Physical vapor deposition (PVD), plating and spraying are some of the other techniques used to produce fiber coatings. When the objective is to increase wettability, the integrity and structure of the coating is less of a concern than if it were to be used as a protective layer. Barrier coatings to protect fibers from chemical attack by the matrix must, in addition to having thermodynamic stability, impair transport of reactants through it. Fluxing action by a reactive salt coating such as K2ZrF6 has been found to promote wettability particularly for C and SiC fibers in aluminum. Sizing of tow based ceramic fibers may be used to enhance handling characteristics.

MANUFACTURING PROCESSES

OVERVIEW AND GENERAL INFORMATION

Choice of the primary manufacturing process for the fabrication of any MMC is dictated by many factors, the most important of which are:

1. Preservation of reinforcement strength

2. Minimization of reinforcement damage

3. Promotion of wetting and bonding between the matrix and reinforcement

4. Flexibility that allows proper backing, spacing and orientation of the reinforcements within the matrix

These primary industrial manufacturing processes can be classified into liquid phase and solid state processes. Liquid phase processing is characterized by intimate interfacial contact and hence strong bonding, but can lead to the formation of a brittle interfacial layer. Solid state processes include powder blending followed by consolidation, diffusion bonding and vapor deposition. Liquid phase processes include squeeze casting and squeeze infiltration, spray deposition, slurry casting (compocasting), and reactive processing (in-situ composites).

ASSEMBY AND CONSOLIDATION

POWDER BLENDING AND CONSOLIDATION

Powder blending and consolidation is a commonly used method for the preparation of discontinuously reinforced MMCs. In this process, powders of the metallic matrix and reinforcement are first blended and fed into a mold of the desired shape. Blending can be carried out dry or in liquid suspension. Pressure is then applied to further compact the powder (cold pressing). The compact is then heated to a temperature which is below the melting point but high enough to develop significant solid state diffusion (sintering). After blending, the mixture can also be consolidated directly by hot pressing or hot isostatic pressing (HIP) to obtain high density. The consolidated composite is then available for secondary processing. Achieving a homogeneous mixture during blending is a critical factor because the discontinuous reinforcement tends to persist as agglomerates with interstitial spaces too small for penetration of matrix particles.

CONSOLIDATION DIFFUSION BONDING

This method is normally used to manufacture fiber reinforced MMCs from sheets, foils, powder, powder tape or wire of matrix material, or matrix coated fibers. The methods of assembling reinforcement fibers and matrix alloys depend upon fiber type and fiber array preform method. In the case of monofilaments, such as SiC and boron, parallel arrays with controlled fiber-to-fiber spacing are generated via drum winding, weaving with metallic ribbons, or feeding one or more filaments into a continuous process. Towbased fibers, such as alumina or graphite (carbon), are typically drum wound or creeled for continuous payout. Matrix materials can be supplied to the composite assembly as separate constituents (e.g., foils, powder mat or tape, wires) or applied directly to the fiber array (e.g., vapor deposition, plasma spray). The composite elements (plies) are assembled by layering (or wrapping for cylindrical or ring shapes) the fiber array and matrix plies to achieve a predetermined fiber orientation and composite thickness. Composite consolidation is achieved by applying a high pressure in a direction normal to the ply surfaces and a temperature sufficient to produce atomic diffusion of the applicable matrix alloy. This process is performed in a vacuum environment.

VAPOR DEPOSITION

Prominent among the vapor deposition techniques for the fabrication of MMCs is electron beam/ physical vapor deposition (EB/PVD). This process involves continuous passage of fiber through a region of high partial vapor pressure of the metal to be deposited, where condensation takes place so as to produce a relatively thick coating on the fiber. The vapor is produced by directing a high power (~ 10kW) electron beam onto the end of a solid bar feedstock. One advantage of this technique is that a wide range of alloy compositions can be used. Another advantage worth noting is that there is little or no mechanical disturbance of the interfacial region which may be quite significant when the fibers have a diffusion barrier layer or a tailored surface chemistry. Composite fabrication is usually completed by assembling the coated fibers into a bundle or array and consolidating in a hot press or HIP operation.

SQUEEZE CASTING AND SQUEEZE INFILTRATION

Porous preforms of reinforcement material are infiltrated by molten metal under pressure to produce metal matrix composites. Reinforcement materials include carbon, graphite, and ceramics, such as oxides, carbides, or nitrides. Reinforcement forms include continuous fiber, discontinuous fiber, and particulate. Metals used include aluminum, magnesium, copper, and silver. The volume fraction of reinforcement in the metal matrix composites varies from 10 to 70 v/o depending on the particular application for the material.

Generally, the preform, which is shaped to match the contours of the mold, is not wet by the molten metal and must be infiltrated under pressure. In squeeze casting, a hydraulically activated ram applies a low controlled pressure to the molten metal to attain infiltration of the preform without damaging it. Infiltration may or may not be vacuum assisted. Once infiltration is complete, a high pressure is applied to eliminate the shrinkage porosity that can occur when the liquid metal contracts as it transforms into the solid state. This complete consolidation, or absence of porosity, provides the squeeze cast metal matrix composite materials with excellent mechanical properties.

SPRAY DEPOSITION

A number of processes have evolved under this category in which a stream of metal droplets impinges on a substrate in such a way as to build up a composite. If the reinforcement is particulate, it can be fed into the spray. Matrix only spray can be applied to an array of fibers. The techniques employed fall into two distinct classes, depending on whether the droplet stream is produced from the molten bath (e.g., the Osprey process), or by continuous feeding of cold metal into a zone of rapid heat injection (e.g., thermal spray processes). In general, spray deposition methods are characterized by rapid solidification, low oxide contents, and significant porosity levels. Depositions of this type are typically consolidated to full density in subsequent processing.

SLURRY CASTING (COMPOCASTING)

Liquid metal is stirred as solid reinforcement particles are added to the melt to produce a slurry. Stirring continues as the melt is cooled until the metal itself becomes semi-solid and traps the reinforcement particles in a uniform dispersion. Further cooling and solidification then takes place without additional stirring. The slurry may be transferred directly to a shaped mold prior to complete solidification, or it may be allowed to solidify in billet or rod shape so that it can be reheated to the slurry form for further processing by techniques, such as die casting.

REACTIVE PROCESSING (IN-SITU COMPOSITES)

There are several different processes that would fall under this category. Directional solidification of eutectics in which one of the phases solidifies in the form of fibers is one such process. Inherent limitations in the nature and volume fraction of the reinforcement and the morphological instabilities associated with thermal gradients have resulted in a decrease in the interest in these types of composites. Exothermic reactions, such as directed metal oxidation, are one family of processes for the production of in-situ composites. The major advantage of this class of composites is that the in-situ reaction products are thermodynamically stable.

POSSIBLE AEROSPACE APPLICATIONS

While MMCs have been used extensively in low temperature aerospace applications, work continues to bring these materials to higher temperature environments. High specific strength is the main advantage cited most often for these applications, given the critical importance of weight in aerospace vehicles. Additionally, impact strength, heat and erosion resistance, and thermal stability are also supremely important in these operations. In low temperature applications, for instance in the fuselage of aircraft or helicopters, high specific strength may be the driving characteristic. In high temperature environments, which may include engine components or airframe applications for vehicles operating at supersonic velocities, heat and erosion resistance, thermal stability, and impact resistance may be the overriding concerns in material selection (Koczak, Khatri, Allison, and Bader, 1993).

INCORPORATING MMCS INTO EXISTING MATERIALS COURSEWORK

THE CURRENT CURRICULUM FRAMEWORK

The Aircraft manufacturing process course (AT 308) in the Aeronautical Engineering Technology program at Purdue University is organized to function as an independent business venture in order to simulate a real world manufacturing experience for students (Dubikovsky,2006). While attention is focused closely on materials, material properties, and manufacturing processes, business aspects relating to these manufacturing processes are studied, as well. The instructor provides detailed instruction on the use of each of the following form and control documents:

- work orders
- process sheets
- engineering drawing
- technical operations bulletins
- revision and deviation request forms

Through the use of these documents over the course of a semester, students become familiar with elements of machining, manufacturing processes, and operations. These experiences and the knowledge gained therein are of critical importance for students learning how to support, maintain, and repair aircraft in the future. In light of the dominant role that aluminum plays in traditional aircraft construction, this material is studied closely for its strengths and properties. In both lecture and laboratory portions of this course, heat treat processes and tempers of aluminum are emphasized, as well. Laboratory exercises include the application of both manual and CNC lathes and mills for machining purposes and small furnaces for heat treating. After heat treat and manufacturing processes are completed, students then follow standard practices to test materials for a number of finished product characteristics.

In this course, students often work in teams to produce finished products. To prepare students for this experience, the instructor addresses elements of teamwork and effective teaming in lecture, and also includes a component of the course grade based on student team performance. Students acquire experience locating, interpreting, and implementing technical data, while they also become familiar with typical commercial aviation policies, practices, and procedures. This is the first materials course in the AET curriculum that focuses on engineering technology, and, therefore, engineering topics including loads and strains, and their implication for structural joints are given considerable emphasis. With this background, students learn elements of design, which they take to projects in the laboratory.

Following successful completion of AT 308, students then enroll in the advanced course for materials, AT 408, which is a final senior level course focused on advanced materials manufacturing. This course is almost entirely project-based allowing students to perform research and design products and again a better understanding of engineering fundamentals and technology applications in industry. It also requires communication and planning skills as students acquire the new language of manufacturing and take projects from planning to hands-on delivery in a team environment. All stages of the design process are involved, as students develop a budget and predict project costs, establish timelines and produce process sheet and work instructions (Dubikovsky, 2007). The students have complete freedom to choose any manufacturing processes and materials for their projects. The one and only requirement is to fulfill a customer's need with newly designed product. Lean Six Sigma methodology, which is well proven and widely used in industry, is practiced in this course. "Lean" is many times understood to be 'reducing waste' or sometimes as the "Toyota Production System". While it is true that Shigeo Shingo of Toyota identified and concentrated on seven wastes, he also made many other contributions. A look at the Toyota Lean principles as presented by Womack and Jones reveals a more holistic picture of Lean (Womack and Jones, 1996) :

1. Define value from the customer's perspective.
2. Identify the entire value stream and eliminate waste.
3. Make the value creating steps flow.
4. Provide what the customer wants only when the customer wants it.
5. Pursue perfection.

While design and manufacture of a useable, airworthy part with timely turnaround is the ideal target in industry, such expectations are projected to be, at times, unrealistic given the real life constraints of laboratory timeframes, limited resources and lack of technical field experience among both student groups. Accommodations are made as necessary in response to the limitations and constraints that pertain in the classroom and laboratory.

INCORPORATING MMCS INTO THE COURSEWORK

When bringing new materials into courses of this nature accommodations must be made in both the lecture and the laboratory. The primary difficulty in lecture relates to the amount of time to cover a new materials area. The instructor may elect to cover only the information required so that students may be able to perform the required laboratory exercises with the materials in question. In the laboratory, time is the most precious commodity, and there is rarely any to spare. If projects are to be added, existing projects must be either pared down or eliminated entirely. Tooling requirements may be significantly different than for other materials, and acquiring such equipment is not a trivial matter. Budgets are most often tightly constrained in any educational setting, leaving little if any funding for purchase of new tooling or additional storage. Also, many specific usages of MMC are not widely known, as this emerging technology involves proprietary information. This shroud of secrecy surrounding these advanced materials makes it very difficult to bring the information to the classroom in a meaningful way.

Given these constraints, the initial steps to incorporate MMCs or other advanced materials may revolve around the development of a unit of study in lecture. As funding becomes available, or as donations of equipment and material occur, the effort may then expand into the practical, hands-on work in the laboratory environment. In lecture, the focus will be on the characteristics of the material, applications in the aerospace vehicle, and standard repair strategies and practices utilized in the field. Incorporation of MMCs faces some uphill battles due primarily to costs. These economic considerations will be analyzed in the classroom, to enable students to explore and develop an understanding of the tradeoffs that exist in the development of new technology and materials. Hazardous material and related considerations must be treated in detail, as well, so that future technicians and managers are well-prepared to handle these critical matters in the field.

CONCLUSION

Although advanced materials present significant challenges for inclusion in technical or engineering technology coursework, generally the existing framework of the curriculum need not change. Presentation of the material in the lecture will occur in a manner similar to that followed with other aircraft materials. The challenge there is generally finding the time in an otherwise tight schedule. The same time challenge exists in the laboratory, but working with the new materials leads to other problems. New tooling may be required, which by itself may extend the development effort significantly. Storage is another concern, as room must be made for the materials, aside from any special handling concerns that may pertain.

Regardless of these problems, it is critically important that education stay abreast of emerging technology and materials. If students are to be ready for and able to compete with their peers in the aerospace industry, they must possess the knowledge, skills, and abilities required to deal with virtually all materials in general use. Study should include the methods used to manufacture the material, material characteristics, applications, and repair techniques and strategies. With advanced materials of this type, repair must first be discussed in detail in lecture, due to the specific technical information involved, and then practical projects are introduced in the laboratory under close supervision. As with any new material, hazardous waste and conditions that may result during manufacturing and repair must be thoroughly covered.

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Northrop Rice Foundation Newsletter

February, 2008 Volume 5, Issue 1

MESSAGE FROM THE PRESIDENT

It seems like every newscast these days is a duplicate of the proceeding one. The main subject of the reporting is the declining economy. The housing situation is affecting the economy, fuel prices are escalating, unemployment is starting to rise and consumer confidence is on a downward cycle. However, one area of the economy that seems to be somewhat immune from the economic downturn is the aviation industry.

The commercial airlines are flying with nearly full airplanes. The corporate airplane manufacturers are having record sales. Private small airplanes are selling well, and during the last two years both large commercial airplane manufacturers Boeing and Airbus have had record sales. This is a situation that is both positive and negative for those of us in the aviation career field.

The positive aspect of the downturn is that it seems more people are using air travel instead of driving personal cars for business and vacation travel. Our busy life styles require us to travel to accomplish our various tasks. As the cost of fuel increases, more people will choose air travel, which will require more airplane capacity. This in turn will require more pilots and qualified maintenance personnel to maintain the airplanes.

Hopefully the increase in the cost of fuel will not cause the airlines to reduce capacity. Instead they can reduce other expenditures allowing them to continue to supply us with the necessary service they now deliver.

The above positive aspect of the present aviation cycle could lead us into a negative one. A challenge that I see — where are the personnel going to come from to fulfill the requirement for additional qualified Aviation Maintenance Technicians? Several industry organizations have predicted a shortage of technicians, however, there has been little discussion and programs on how to minimize the impact of a predicted shortage.

Another factor is that a significant number of current Aviation Maintenance Technicians are of "baby boomer" age and these people are nearing retirement, thus leaving their positions in the industry at the same time an increase in technicians will be required.

The Northrop Rice Foundation spent some time during the last Board meeting reviewing our present Mission, Goals and Operating Procedures. We had the benefit of an individual qualified to lead us through this activity that has resulted in our having a much clearer picture of our future activities.

As a result of this important meeting I feel we are developing a Foundation operating plan that will assist the industry in meeting this shortage challenge.

(Continued on page 3)

Inside this issue:

Board Member Highlight

Jim Lukins has been in aviation for over 50 years. His first aviation experience was as an aviation maintenance technician after attending a Navy school. He served as a flight engineer until his discharge after five years of active duty.

Jim then attended Iowa State University where he graduated in 1961 with a BS degree in Aerospace Engineering.

Jim was recruited by Boeing to assist in the introduction of the 727 and later models of the 707. From 1961 until 1985 he was involved in the flight area in charge of airplane performance and certification. He worked on the Boeing 737, 747, 757, 767 and 777 airplanes.

In 1985 Jim was asked to assume the responsibilities of Director of Maintenance Training, an assignment he continued with until his retirement from Boeing in 1995.

After retirement he participated in consulting activities during which time he was asked to join the Northrop Rice Foundation.

Jim is dedicated to improving the status and work environment of the Aviation Maintenance Technician.

Recent Board Activity

The beginning of the year is always hectic for many of the NRF Board members. Throughout the fall and winter months, we distribute email announcements for all of our scholarships and awards. An email blast is sent out approximately every two weeks to those schools listing an email contact address in the ATEC catalog.

At the beginning of March when the scholarship deadline occurs, all Board members actively participate in the review and evaluation of the many applications.

Along with the Board meeting in February, several Board members attended aviation conferences including Women in Aviation (WIA) in San Diego and HeliExpo (HAI) in Houston.

We apologize for the delay in sending out our February newsletter!

The Northrop Rice Foundation Newsletter will be published three times a year - February, June and October. If you have any suggestions on articles or information you would like to see in the NRF Newsletter, please contact Alice Rice at 281-334-5932 or email at mar246@juno.com

Northrop Rice Foundation
Telephone: 713-644-6616
Fax: 281-334-0335
Web: www.northropricefoundation.org

For information about the activities of the Foundation or to obtain details about any of the programs described in this newsletter, visit the Foundation web site at www.northropricefoundation.org, or email a request for information to Ivan D. Livi, at ivan.livi@verizon.net, or nrf@alphabravo.com.

MESSAGE FROM THE PRESIDENT, *cont.*

Over the next few issues of this newsletter we will discuss our future activities and how we plan to support the aviation industry. We are proud of our past accomplishments and look forward to providing even better support to the industry.

We can only achieve our significant goals if we have the resources to work toward their accomplishment. All Northrop Rice Foundation Board Members are volunteers and spend many hours on our programs. We are dedicated to supporting aviation as the primary method of travel and to making it the safest and most economical mode of transportation.

As always we need your support, both financially and in material gifts. Please become or continue to be a member of the Foundation. Encourage your co-workers to join us. If possible, please provide us with a tax deductible contribution that can be used to enhance the education and training of our future aviation maintenance technicians.

Jim Lukins, President

NORTHROP RICE FOUNDATION ADDS BENEFITS PROGRAMS

This year the Northrop Rice Foundation has added several scholarships and awards programs to the list that it administers. Presently, there are nine programs that provide financial assistance, books, tools, and training equipment for students, instructors, and schools. Announcement of this year's recipients of the donated items will be made at the Annual Conference of the Aviation Technician Education Council in Las Vegas, NV on April 7, 2008. Members of the Board of NRF together with members of the ATEC Member Services Committee have served as Selection Committees and have reviewed and processed approximately seventy-five applications for the different scholarships and awards categories.

Additional programs are being implemented for the coming year. The James Villnave Memorial Scholarship will make available funds for student tuition, instructor assistance, and assistance for recently discharged veterans of the branches of the US Armed Forces. Information and applications are available from the NRF and ATEC web sites. The Northrop Rice Foundation is also joining efforts with the AMT Society which will provide more scholarship availability for people who are primarily in aviation maintenance. These scholarships will be available to aviation maintenance personnel working or training to work in a number of segments of the aviation industry.

Sponsors who are willing to participate in similar programs by providing financial assistance, books, tools, or training equipment are being solicited. Sponsors who, through their generosity, can donate to the Foundation so that it can continue to maintain these types of programs are very welcomed.

Partnerships with other aviation organizations are being investigated by the Northrop Rice Foundation in an effort to expand the availability of benefit programs for aviation maintenance personnel. Any sponsor interested in participating in these efforts please contact Ivan D. Livi, at ivan.livi@verizon.net.

Ivan D. Livi is Vice President, Northrop Rice Foundation and Co-chair, ATEC Member Services Committee

Northrop Rice Foundation
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NORTHROP RICE FOUNDATION NEWSLETTER
February, 2008—VOLUME 5, ISSUE 1

Aviation Rulemaking Advisory Committee (ARAC)

The following information was derived from the minutes of the ARAC Executive meeting held on December 5, 2007 in Washington DC.

The Part 147 Working Group, chaired by Dr. Raymond Thompson, was tasked in June 2007 to (1)evaluate §§ 147.21 and 147.31 and Appendices A through D of 14 CFR Part 147 and recommend ways that would enable AMT Schools to meet the needs of clientele more effectively and (2) evaluate and incorporate revisions granted by exemptions to 14 CFR §§ 65.75(a) and 65.77.

An organizational meeting was held in September, 2007 and a working meeting was held November 28-29, 2007. During these meetings work plan objectives were developed, an ambitious meeting schedule was established and the group completed its review of Appendices A through D.

Dr. Thompson reported to the ARAC Executive committee that one of the obstacles the working group is facing is determining how flexible can it make the curriculum while still upholding the curriculum's current structure and clear manipulative standards. The working group wants to be able to update the curriculum requirements to respond to new technology without always having to revise the regulations. He stated that the working group has a good idea of what the curriculum should look like but putting it in the regulations is hard.

It was suggested that the working group look at the structure of 14 CFR Part 141 as well as the airworthiness standards. It was noted that if the regulation changes the written, oral and practical exams will need to be changed.

The working group was advised to submit its final product at least 30 days before the next scheduled ARAC Executive meeting in June, 2008.

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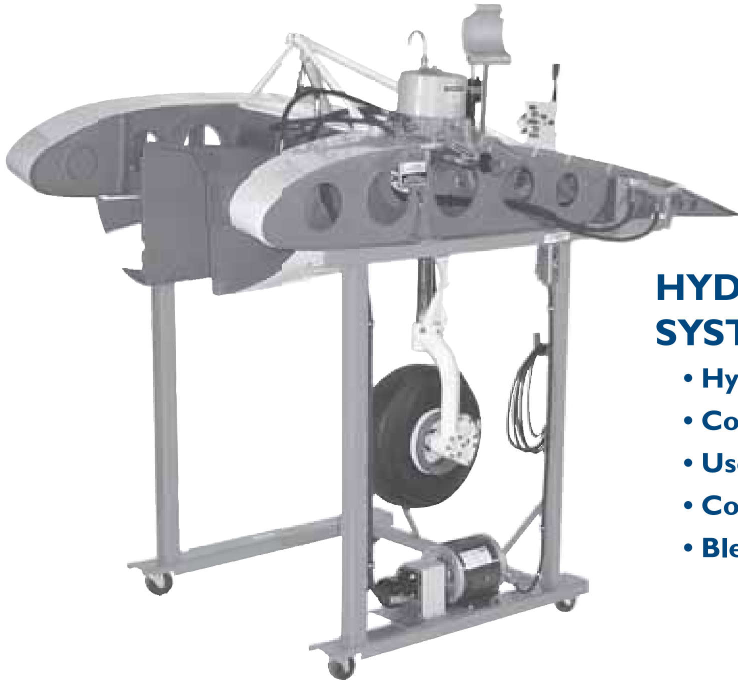

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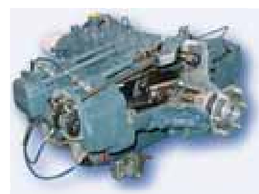

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ATEC Update

ATEC CONFERENCE

Over 120 participants from 70 schools and 34 exhibitors from 20 companies attended the 48th Annual ATEC Conference in Las Vegas on April 6-8.

While most participants rated the networking opportunities quite positively, the most highly rated programs were:

1. Boeing 787: The New Technology
2. Soft Skills in Aviation Maintenance Labs
3. 147 ARAC: Final Input
4. Skycatcher – LSA
5. Medical Issues in the 147 Curriculum
6. Top Ten Mistakes New Grads Make in a Job Search

In 2009, ATEC will hold its Annual Conference at the Holiday Inn International Drive Resort in Orlando on April 19-21, just prior to the nearby Sun and Fun Air Show.

Then in 2010 ATEC will take a break from Vegas and go to Phoenix, Arizona, April 11-13 for the 50th Annual ATEC Conference at the Marriott Mesa Resort.

147 ARAC

The rewriting of PART 147 is scheduled to be completed by June 2008. Once the ARAC issues its report, the proposed rule will begin the regulatory review process where there will be ample time for comments by schools and the aviation industry in general.

At the ATEC Conference in Las Vegas, it was reported that the ARAC is seriously considering changes to PART 147 that would:

- allow curriculum updates for easier changes so schools can keep current with industry needs
- provide changes in hours within the curriculum section
- allow for more flexibility and fewer restrictions so schools may change and introduce new technology that students need for the employers a school serves
- make it clear to inspectors what the rule means to ensure consistency
- allow for alternative methods for curriculum delivery e.g. on-line
- include human factors
- increase composite hours
- address make-up hours

However, it was made clear that the total minimum hours will remain at 1900.

Comments are still being accepted. Send your input to ATEC at ccdq@aol.com by April 30 and we will forward them to the ARAC Chair, Ray Thompson, who is also ATEC's Vice-President.

INDUSTRY MEMBERS

ATEC is looking for additional industry members to help provide us with input and suggestions regarding what aviation companies need in the way of specialized skills – how schools can provide a better A&P to industry.

Let us know of any companies you work with that may want to join ATEC and be part of that discussion.

ELECTION RESULTS

At the Conference, the following people were elected or re-elected to the ATEC Board.

(2010) Laurie Johns, President – Columbus State Community College

(2010) Ray Thompson, Vice President – DAE University

(2011) Joe Hawkins – Middle Tennessee State University

(2011) Brian McGlynn – Lane Community College

(2011) Mike Gehrich – Vincennes University

(2011) Harry Whitehead – Lansing Community College

ATEC WEBSITE AND E-JOURNAL

As you review the updated ATEC Website, please send any recommendations for improvement to domenic.proscia@vaughn.edu.

The ATEC peer reviewed e-Journal is now being sent to 650 people. If you are not receiving a copy twice a year and you would like a copy, send an e-mail with your e-mail address to domenic.proscia@vaughn.edu.

VIDEOS TO DVDs

Over 80 ATEC videos have been converted to DVDs so far.

Southwest Airlines recently donated several new videos.

Find them all on the Website www.atec-amt.org. Click on “Curriculum Resources.”

SURPLUS EQUIPMENT

At the ATEC Conference, Dan Tobin, Director of the FAA Asset Management and Equipment Reutilization Office, described how schools can access surplus FAA equipment without surcharge before it is sent to GSA.

The Asset Management and Equipment Reutilization Office in the FAA manages the Stevenson-Wydler Act for Technology Innovation.

The Asset Management Office transfers excess property from NASA and the armed forces to institutions of higher education, as well as technical schools.

- Equipment must be used for direct educational purposes.
- It cannot be transferred for administrative support.
- Recipient pays for transportation but there is no administrative fee since it does not go through GSA.
- Title to the equipment transfers.
- Property must be serviceable and in working order.

Property that has been available and transferred to educational institutions in the past:

- Aircraft
- Aircraft and Engine Components
- Non Destructive and Destructive Test Equipment
- Aviation Hardware including Tubing, Hose and Fittings
- Metal, Fabric, and Composite Material
- Aircraft Support Equipment
- Flight Simulators

To access this property before it gets sent to GSA, the school sends a "want list" to the FAA Regional Property Disposal Officers. To get a phone number, please contact the ATEC Office at ccdq@aol.com. They will search their data base for the requested property. They will then contact you if they find anything that meets your specs to see if you want it.

You can also ask to see the surplus equipment list each week so you can check it for yourself.

ATEC Awards

The Jim Rardon Student of the year award was given to Shawn Smith from Pittsburg Institute of Aeronautics.

Flight safety Inernational Scholarship was awarded to Lane community college, accepted by Brain Mcglynn.

ATEC ANNUAL CONFERENCE AWARDS

LAS VEGAS, NV **APRIL 7, 2008**

S&K HAND TOOL COMPANY TOOL SETS SCHOLARSHIPS

1. Lized Masache — Teterboro School of Aeronautics
2. Brendan Huernergardt — San Joaquin Valley College
3. Quina Wade — Aviation Institute of Maintenance

WING AERO AVIATION BOOK AWARDS

1. Victor Udechukwu — Pittsburgh Institute of Aeronautics
2. Abel Almaguer — Aviation Institute of Maintenance – Orlando
3. Kevin Barkley — Middle Georgia Technical College
4. Shawn Smith — Pittsburgh Institute of Aeronautics
5. James Park — Idaho State University
6. Donald Merriam — Spokane Community College
7. Kane Wallick — Pittsburgh Institute of Aeronautics

DALE HURST MEMORIAL SCHOLARSHIP AWARD

Reedley College Instructors, Reedley, CA

Robert Takacs

Keith Zielke

David Richie

SOUTHWEST AIRLINES SCHOLARSHIP

Dennis Fisher, Pittsburgh Institute of Aeronautics

FLIGHTSAFETY INTERNATIONAL SCHOLARSHIP

Brian McGlynn, Lane Community College

ROTORCRAFT ENTERPRISES, INC. AWARD

Middle Tennessee State University

NIDA CORPORATION AWARD

Pitsburgh Institute of Aeronautics

Jeppesen appoints Aircraft Technical Book Company for e-Book distribution of flight and maintenance training manuals.

Aircraft Technical Book Company, the leader in electronic distribution (e-Books) in the aviation industry, will now offer Jeppesen pilot and maintenance training manuals in e-Book format as well as in standard printed format.

According to Andrew Gold, president of Aircraft Technical Book Company, e-Books are about giving our customers a choice in how they receive content. While many of us will always prefer a printed book, the e-book format also has many advantages. The first of which is free and instantaneous shipping; a significant savings for our international customer, for distance learners, and for our military personnel stationed overseas. Also, for international customers, e-Books incur no VAT tax, import, or brokerage fees, itself a huge savings. e-Books from Aircraft Technical Book Company are delivered on a single high quality Adobe .pdf files, are fully searchable, printable, and environmentally friendly - not requiring transport, paper, or even ink.

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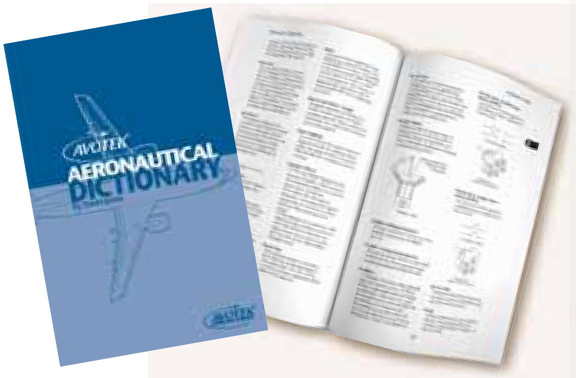

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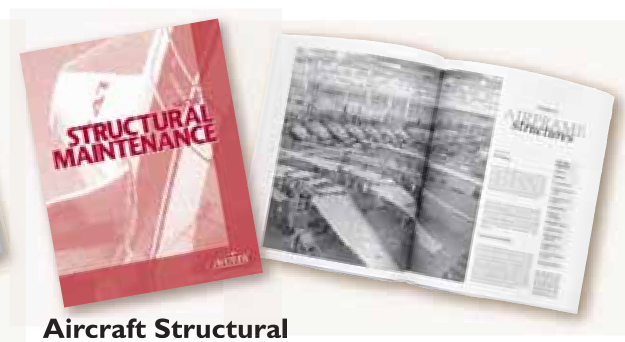

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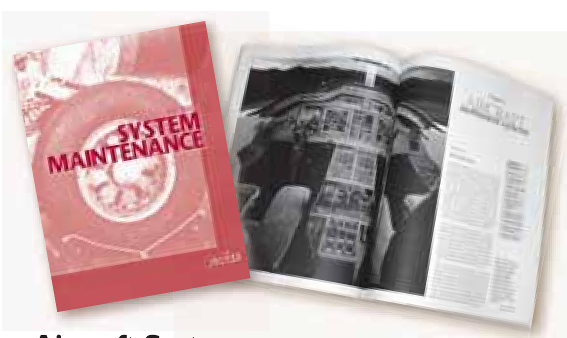

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